

DEPARTMENT OF THE NAVY
BUREAU OF STEAM ENGINEERING
N. S. E. 245

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ENGINEERING INSTRUCTIONS

1917



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ENGINEERING INSTRUCTIONS.

These instructions are incorporated at present in the Naval Regulations and Instructions, 1913, as chapter 27. Inasmuch as this book is not readily accessible to the enlisted personnel, the bureau considers it of first importance that the engineering instructions, which relate especially to such matters as are essential in the care, preservation, and operation of the boilers and machinery to prevent injury, to insure their safety, and to secure the most efficient and economical performance, should be made available for the information and guidance of all members of the naval service.

In addition to the instructions contained herein, all officers and men are to be guided in the use and management of boilers, fuel-oil burning installations, evaporating plants, ice machines, and pumps by the more detailed and specific instructions given in the pamphlets relating particularly to these machinery units which have been furnished for their information.

R. S. GRIFFIN,
Engineer in Chief, United States Navy.

NAVY DEPARTMENT,
Washington, D. C., April 7, 1917.

The "Engineering Instructions" contained herein are approved for issue to the naval service for information and guidance. The instructions will be followed on all vessels.

JOSEPHUS DANIELS,
Secretary of the Navy.

ENGINEERING INSTRUCTIONS.

Section 1.—TRIALS OF MACHINERY; GENERAL INSTRUCTIONS.

1. Object of trials—

Machinery trials of vessels of the Navy shall be held from time to time for the purpose of ascertaining the capabilities of the engines, boilers, and appurtenances, either in connection with the contract requirements for new vessels prior to their final acceptance, or to determine their efficiency under service conditions, the extent of repairs necessary, the sufficiency of repairs that have been made, or the most economical rates of performance under various conditions of service.

2. Kinds of trials—

The following trials shall be carried out under the conditions specified:

- (a) Preliminary acceptance trial.
- (b) Commissioning trial.
- (c) Final acceptance trial.
- (d) Post-repair trial.
- (e) Laying-up trial.
- (f) Engineering competitions and special trials.

3. Boiler tests before trials—

Prior to a machinery trial, each boiler that has been longer than six months without having had full pressure of steam raised in it shall be subjected to a test by cold-water pressure and to a test by steam pressure. The water pressure applied shall be 25 per cent in excess of the authorized safety-valve setting. Steam pressure shall be

raised and maintained for at least one hour at a pressure of not less than 95 per cent of the authorized safety-valve setting, after which the boiler, with the water retained in it, shall be allowed to cool off. Throughout these tests, and afterwards when cold, the boiler shall be carefully and thoroughly examined for indications of any defects or weakness, particularly as to the tightness of the shells, drums, joints, tubes, nipples, manhole and handhole plates, and other pressure parts.

4. Inspection of boilers before raising steam for tests—

Previous to raising steam for testing the condition of boilers, care shall be taken to see that the dry pipes are clear and their openings not clogged, that the internal feed pipes are well secured, and that the zinscs are efficiently connected and in proper condition. The following parts, with all gear connected to them, shall be examined and actually worked to see that they are in proper condition:

- (a) Main auxiliary stop valves.
- (b) Safety and sentinel valves.
- (c) Surface and bottom blow valves, pipes, and sea valves.
- (d) Steam and water gauges, cocks, and pipes.
- (e) Feed check and stop valves and pipes.
- (f) Drain cocks and pipes.
- (g) All other boiler fittings connected with the safety of operation and management.

5. Inspection of engines before trial—

Previous to working the engines for trial the following parts shall be examined and worked as far as possible:

- (a) Pistons, rings, springs, followers, and their fastenings.
- (b) Main stop, throttle, and by-pass valves.
- (c) All relief valves, drain cocks, and traps.
- (d) Reversing gear, hand and steam, and other starting gear.

(e) Sea suction and discharge valves in connection with the condensers, pumps, and main engines.

(f) All couplings, nuts, keys, etc., connecting the various working parts, and all important holding-down bolts and other fastenings of the machinery shall be examined and carefully sounded.

(g) The tightness of the condensers and tubes shall be tested.

(h) Main air, circulating, feed, and hot-well pumps.

(i) Feed water heaters and grease extractors.

6. Report of engineer officer prior to trial—

When all of the examinations required by articles 3, 4, and 5 have been made, and not later than the day before steam is to be raised for a trial, the engineer officer shall report to the commanding officer that the boilers and engines are in proper condition and fit to proceed with the trial, or state wherein any part is, in his opinion, not in a safe and proper condition.

7. Action if machinery is unsatisfactory—

If, in the opinion of the commanding officer, the condition of the machinery or boilers is such that either may be seriously injured or disabled by the trial about to be undertaken, the trial may, with the approval of the senior officer present, be postponed until the circumstances can be reported to the department and further instructions received.

8. General rules for trials—

The following general rules shall be observed during all full-power trials, and during other machinery trials to which they may be applicable and consistent with the conditions imposed:

(a) The engines shall be worked so as to use all the steam made by the boilers with the pressure maintained as near the designed working pressure as practicable, and the

steam pressures, vacuum, number of revolutions, and other variables shall be kept as nearly uniform as possible.

(b) The speed of the engines shall be gradually increased to the maximum attainable under the conditions imposed. Before starting a full-power trial, the engines should be worked at about three-quarters power for a sufficient time to allow the boilers to be brought to proper steaming condition after forced draft has been started.

(c) No full-speed trial shall take place in less than forty fathoms of water; depth of water shall be reported.

(d) Care must be taken to obtain correct weight or measure of the fuel used and that the fires are in the same condition at the end of the trial as at the beginning. The kind and quality of the fuel used shall be specifically stated in the report of the trial.

(e) Coal shall not be hand picked but shall be used as it runs from the bunkers.

(f) The engine room and fireroom watches shall be so arranged, if practicable, that every man of the engineer's force, except such as are regularly assigned as messmen or to other special duties and are not ordinarily available for watch duty, will be on duty for a portion of the time whenever forced draft is used on these trials.

(g) During full-power trials, except such as may be forbidden by the current rules for engineering competitions, the deck force shall render any assistance necessary to provide sufficient fuel in the firerooms, the amount of such assistance being mentioned in the report of the trials.

(h) Salt water shall not be fed into the boilers during any of these trials if it can be avoided. To this end, an ample reserve supply of fresh water shall be provided in advance of the trial, and the evaporators will be run to make up extra feed if necessary.

(i) Should it be found desirable to continue a four-hour full-power trial beyond the four hours from the beginning,

the observations shall be continued until the trial is finished. Then the four consecutive hours shall be taken which are to be considered as the trial period, and the difference of the counter readings at the beginning and end of this period divided by 240 will give the mean revolutions per minute for the whole period for each screw. The mean of the revolutions for all the screws will be the mean for the trial. The foregoing assumes that during the trial there has been no material variation from the average speed. However, should there be a material variation for a short period, due to heated bearings or other causes, and it is nevertheless decided to have the four-hour period in which it occurs counted as the trial, the following modifications shall be followed. The counter readings at the beginning of the trial shall be subtracted from those at the beginning of the reduced speed; the difference of the readings divided by the time which elapsed in minutes, and the average revolutions thus determined for this period as already explained for the four-hour period; from this the average speed up to that time shall be determined and thereby the number of miles run during that period. In the same way find the average speed and number of miles run for the time of the reduced revolutions, and also for the period from the end of the reduced revolutions to the end of the trial. The three distances run shall then be added together and their sum divided by four, which will give the average speed per hour during the four-hour trial.

9. Report of results of trial—

The results of all machinery trials shall be fully reported to the department, with all the attending circumstances, especially the mean draft and corresponding displacement of the ship at the beginning of the trial, the condition of the ship's bottom, the time since last docked, the average horsepower developed by the main and auxiliary engines, the consumption of fuel per hour, the distance run per ton

of fuel, the pounds of fuel consumed per mile, the average speed of the ship with all corrections applied, and the average number of revolutions of the propelling engines. The auxiliaries in use during the trial shall be stated. The methods by which the speed was determined shall be described. The report shall state whether the machinery is in a satisfactory condition; if its condition is not found satisfactory, all defects and deficiencies shall be fully described and recommendations made for correcting them. Reports of trials held under the Rules for Engineering Competitions shall be made as prescribed in the rules.

10. Data for determining power—

When practicable during machinery trials the main engines shall be indicated a sufficient number of times, depending upon the length of the trial, to obtain a reasonably correct determination of the average power developed for the period of the trial, which observations shall be taken at intervals not greater than one hour, and which shall be at least three in number, regardless of the length of the trial. Where torsion meters are fitted, a corresponding number of torsion-meter observations shall be taken on ships fitted with turbine propelling engines. The auxiliary engines in operation shall be indicated likewise, unless their power has previously been determined under similar conditions. The power of auxiliary engines not fitted for indicators shall be estimated. Observations of the data required for the steam log shall be taken at half-hour intervals.

Section 2.—PRELIMINARY ACCEPTANCE TRIAL.

11. When held—

Prior to the preliminary acceptance and delivery of a new vessel built under contract, or of new machinery, if contracted for separately, the vessel and machinery shall be subjected to official trials to test her, her speed, and her

machinery. In such cases the conditions and requirements of the trials are fully specified in the contract under which the vessel or machinery is built. These trials shall be held when the vessel and machinery are substantially complete, except such minor items of work as may, in the discretion of the Secretary of the Navy, be left until after the trials, and when the contractors shall have made sufficient trials at dock and in free route to be reasonably sure of satisfactorily meeting the requirements of the contract, and when the contractors shall have notified the Secretary of the Navy that they are ready to submit the vessel or machinery for such trials. In the case of vessels built at a navy yard the preliminary and final trials shall be combined into one trial.

12. Functions of board—

The board of inspection and survey shall be ordered to attend these trials for the purpose of making an examination of the vessel and her equipment and of witnessing and reporting upon the performance of the vessel and her machinery. The board shall be furnished with copies of the contract and specifications for the construction of the vessel and machinery and shall be guided in the performance of its duties by the contract, plans, and specifications, and duly authorized changes therein, and by such specific instructions as the Secretary of the Navy may include in the precept. As the responsibility for the success of the trials rests with the contractors, the board shall have no control over the vessel or machinery, but merely over the instruments for recording data; and the contractors shall not be interfered with in the management of the vessel or machinery.

13. Duties of board—

At all times while the vessel is under way the board shall carefully observe the performance of the vessel and of the

machinery, and, upon the conclusion of the trials, shall make a full and detailed report to the department. This report, in addition to noting any and all circumstances having any material effect upon the working of all the machinery, shall include a statement of the horsepower developed. It shall be accompanied by standardization data; curves of speed, power, and revolutions, and of water and fuel consumptions; a synopsis of the trial; and comparisons of steam gauges, if furnished. The report shall also include a statement of the weight of the machinery, including the water in the boilers and surface condensers, etc., as covered by the contract; of the opinion of the board as to the working of all parts of the machinery, and as to whether the performance is in all respects satisfactory; as to whether the machinery, including the engines, boilers, and appurtenances is strong and well built and in strict conformity with the contract, drawings, and specifications, and the authorized changes therein; as to whether the machinery, including the engines, boilers, appurtenances, and spare parts, is complete in conformity with the contract, drawings, and specifications, and the authorized changes therein, and if not so complete, a detailed list of all the items which are incomplete. The opinions called for herein shall be formed by careful observation and inspection during the trial and by inspection of information furnished by the inspector of machinery at the works of the contractors. The object of this report is to give the department the fullest possible knowledge of the condition and working of the machinery, and nothing shall be omitted that will conduce to that end.

14. Duties of inspector of machinery—

(1) The inspector of machinery at the works of the contractors, or one of his assistants, shall be ordered to report to the board of inspection and survey when it

assembles for the trial of a vessel. He shall furnish the board with such information as it may require, afford it every facility for the examination of the plans and papers relating to the vessel, and render the board all the assistance it may require in the performance of its duties.

(2) He shall be required to report to the board the following information:

(a) The exact weight of the machinery, including the water in the boilers, surface condensers, and other parts of the machinery, in accordance with the contract.

(b) Whether the machinery, including the engines, boilers, and appurtenances, is strong and well built and in strict conformity with the contract, drawings, specifications, and duly authorized changes therein.

(c) Whether the machinery, including the engines, boilers, appurtenances, and spare parts, is complete in accordance with the contract, drawings, specifications, and authorized changes therein, and if not so complete, he shall include a detailed list of all the items which are incomplete.

(d) A tabulated statement showing the results of comparisons between all steam gauges and a standard gauge and the corrections to be applied in all cases.

(e) A statement that the boiler safety valves have been set by actual steam pressure to the pressure designated by the Bureau of Steam Engineering. This statement shall be certified by the person witnessing the test.

(f) Curves of revolutions and horsepower, and water consumption, if practicable, for all the auxiliaries that will be used during the trials, as determined by tests of the same made during preceding trials of such machinery.

(g) A copy of the synopsis of the machinery and hull data filled out, as regards constants and fixed data, as completely as can be ascertained previous to the trial.

(3) Previous to the trial the inspector of machinery at the works of the contractor shall see that the necessary arrangements for measuring fuel and water in accordance with the requirements of the contract are perfected and their efficiency thoroughly tested, and that all special instruments supplied by the department for the purpose of making signals and for measuring and recording data are fitted as required and tested to insure successful operation during the trials.

15. Post-trial examinations—

After the trials have been completed the inspector of machinery may be directed to make a post-trial examination, as the board of inspection and survey may indicate, of such parts of the machinery as would show injury, if any occurred, or defective conditions, if any are likely to be present, and to report the results, with his recommendations, to the board and department. When such post-trial examination is made by members of the board the inspector of machinery shall be present and shall afford all assistance and information desired.

16. (a) The report of the board that conducts the preliminary acceptance trial shall contain work lists under the "Bureau of Construction and Repair," "Bureau of Steam Engineering," and "Bureau of Ordnance." Under each bureau the lists shall be itemized under five heads, viz:

(1) *List A.*—Items of work recommended for which the contractor is considered responsible.

(2) *List B.*—Items of work recommended for which the contractor is not considered responsible.

(3) *List C.*—Alterations recommended, contractors not responsible.

(4) *List D.*—Alterations requested and not recommended.

(5) *List E.*—Items already authorized.

(b) The board of inspection and survey shall prepare its report on sheets 8 by 10½ inches in size and shall distribute copies as follows:

Navy Department (solicitor).....	Original.
Bureau of Construction and Repair (one to be carbon backed).....	Four copies.
Bureau of Steam Engineering.....	Two copies.
Home navy yard of vessel.....	One copy.
Commanding officer of vessel.....	One copy.
Chief of Naval Operations.....	One copy.
Bureau of Ordnance (of that portion of the report which refers to ordnance matters).....	One copy.

Immediately upon receipt of the above reports by the Bureau of Construction and Repair, that bureau will forward one copy each to the superintending constructor and the contractor, and upon completion of the necessary blue-print copies will forward one to the Bureau of Ordnance, one to the inspector of ordnance, and two to the home yard where the vessel is delivered, for the use of the hull and machinery divisions. Copy for the inspector of machinery will be furnished by the Bureau of Steam Engineering. One copy furnished the Bureau of Construction and Repair and one copy furnished for the use of the Chief of Naval Operations shall be returned to the board's files after having served their purpose.

(c) Upon the receipt of copies of the report of the preliminary trial by the superintending constructor, inspector of machinery, and the inspector of ordnance, each of these representatives will request the contractor to complete all uncompleted work, and to correct such defects as appear, in the board's report, under the cognizance of the bureau which he represents, and for which the board considered the contractor responsible. This work should be expedited in order that the vessel may be delivered as promptly as possible after the preliminary acceptance trial is completed. The superintending constructor, inspector of

machinery, and the inspector of ordnance shall forward to their respective bureaus, with pertinent comment and recommendation, such statements as the constructor desires to make in regard to the uncompleted work and defects.

(d) Upon the delivery of the vessel to the Government the superintending constructor and the inspector of machinery shall forward to their respective bureaus detailed statements of any uncompleted work, under their cognizance, on the vessel, together with estimates of the amounts of money which should be reserved on each such item.

(e) Upon receipt, by the commandant of the navy yard at which the vessel is delivered, of the report of the preliminary trial, and after the delivery of the vessel, an examination shall be made and estimates, with pertinent comment and recommendation, shall be submitted to each bureau concerned, on the items of work which remain uncompleted.

(f) The uncompleted work at time of delivery shall be completed if practicable prior to final trial.

(g) The president of the board of inspection and survey, being ex officio president of any trial board (Art. R. 157(7)), the original and all copies of the report shall be forwarded to his office for distribution, except when such procedure would result in material delay, in which case the senior member present shall furnish the navy yard and the commanding officer of the ship with the required number of copies of the report, and shall notify the president of the board of inspection and survey to this effect when forwarding the original of the report.

Section 3.—COMMISSIONING TRIAL.

17. Object of trial—

The object of a commissioning trial is to determine the exact condition of the machinery of a vessel upon going

into commission; whether the machinery has received proper care and attention and been maintained in all respects efficient and ready for service during the time the vessel has been out of commission, in commission in ordinary, in commission in reserve, or under repair; what power can be developed and maintained by the engines and boilers after extensive repairs or alterations have been made; to test the efficiency and sufficiency of such repairs or alterations; to determine what speed the ship should be expected to attain at full power under service conditions during her commission; to familiarize the engineer's force with the conditions attending the working of the boilers and machinery under full power; and to afford experience in working the boilers under forced draft.

18. Dock trials—

Whenever a ship is fitting out at a navy yard and her machinery is reported by the engineer officer of the yard to be complete and in proper order, the commandant shall, as soon as practicable after the engineer officer of the ship reports for duty, direct the engineer officer of the yard, in conjunction with the engineer officer of the ship, to make such trial of the machinery, with the ship secured to the dock, as will enable them to ascertain its exact condition. If, as a result of such trial, any defect, deficiency, or mal-adjustment is discovered by them, the commandant, on their report, shall have it corrected, supplied, or remedied and another trial made, and this procedure shall be repeated until the condition of the machinery is reported satisfactory.

19. Report of dock trial—

In connection with such dock trial the examinations required by articles 3, 4, and 5 shall be carefully and thoroughly made by the engineer officer of the yard and the engineer officer of the ship, or by their representatives, the results of which shall be included in their report. The

report shall also state the condition of the steam and water piping; separators; electric generators and their appurtenances; evaporators and distilling plant; refrigerating plant; all apparatus for extinguishing fire and for pumping out the bilges; all other appliances for the safety, operation, and management of the ship for which the engineer officer of the ship is responsible; the setting of the safety valves on the boilers and of the relief valves on the engines (with a copy of any existing authority for any change that has been made from that stated in the machinery specifications), and a statement of the maximum pressure at which they can be worked; and whether the proper amount of spare parts, tools, instruments, and stores are on board.

20. Certificates of officers conducting trials—

Upon the satisfactory completion of such examinations and dock trials the engineer officers of the yard and ship shall make a joint report to the commandant, to be forwarded to the Navy Department, that they have examined the machinery and tested it by working, and that it is in all respects complete according to its design and in proper order for sea service. Copies of this report shall be retained by the engineer officers for the files of their offices.

21. Training of personnel—

Immediately after being commissioned every vessel shall begin diligently to train the engineer force in preparation for the full-power commissioning trials. During this preliminary training period, in order to familiarize the engineer force with the operation of the boilers and machinery under forced-draft conditions, advantage shall be taken of every favorable opportunity to make runs of from four to six hours under forced draft, using such number of boilers as are under steam at the time these runs are ordered or as may be desirable to best promote the purpose of progressive training. It is important that a vessel should carry out training of this nature early in her commission

in order that she may, as soon as possible, determine the result of such repairs or alterations as may have been made to the machinery prior to commissioning, and also develop an efficient engineer force, which will define her tactical value as a fighting unit of the fleet.

22. Full-power trial—

Except in the cases of new ships (or machinery) when in their first commission (in which cases the final acceptance trial will be substituted) each newly commissioned ship shall, as soon as the engineer force has had sufficient experience to operate the machinery with all the boilers under forced draft, carry out a full-power trial of not less than twelve hours duration. This shall include a period of not less than four hours at the maximum power under forced draft and a period of not less than eight hours at the maximum power attainable with natural draft. This trial shall be witnessed and reported on by the board of inspection and survey. Prior to this trial, a standardization trial shall be held, if practicable, in order to determine proper curves of speed, revolutions, and horsepower. (Art. 39.) The horsepower developed on the four hours forced-draft trial shall be sufficient to fully test the capabilities of the machinery and to establish a standard for full power under service conditions.

23. Examination of machinery after trials—

As soon as practicable, after the completion of the full-power commissioning trials a careful and thorough examination shall be made of such parts of the machinery as shall be designated by the board of inspection and survey for the purpose of ascertaining if any defects exist and if the machinery is in all respects in proper condition. This examination shall be conducted by the engineer officer of the ship, who shall report the result to the commanding officer, fully describing any defects or improper conditions found. The commanding officer shall forward this report,

with his comments, together with the report required by article 9, to the department (Board of Inspection and Survey).

Section 4.—FINAL ACCEPTANCE TRIAL.

24. Object of trial—

In case of preliminary or conditional acceptance of a new vessel or of machinery built under contract or at a navy yard, such vessel and machinery shall be finally tried after the vessel has been fully equipped and armed (or weighted accordingly), and in all respects has been made complete and ready for service. The contracts in such cases provide that such final trials, under conditions prescribed or approved by the Secretary of the Navy, shall take place within a specified period, usually six months and ten days, after preliminary or conditional acceptance. The object of such trials is to determine if there shall have appeared any weakness, defect, failure, breaking down, or deterioration, other than that due to fair wear and tear, through fault of the contractors, and which have not been corrected and made good by them, to the end that the cost of remedying such defects and deficiencies as shall not have been so corrected may be deducted in final settlement from the reservation previously made in preliminary settlement to cover uncompleted and unsatisfactory work.

25. Functions of board—

The board of inspection and survey shall be ordered to attend these trials for the purpose of witnessing and reporting upon the condition and performance of the vessel and machinery. The board shall be furnished with copies of the contract and specifications for the construction of the vessel and machinery, together with the report of the board appointed to witness and report upon her preliminary acceptance trial, and shall be guided in the perform-

ance of its duties by the contract, plans, and specifications, and duly authorized changes therein, and by such specific instructions as the Secretary of the Navy may include in the precept. The contractors may, if they so desire, have a representative present during the trials, who shall have opportunity to observe and inspect the working of the vessel and machinery in all their parts, but without any directing or controlling power over the same.

26. Duties of ship's personnel—

These trials shall be conducted by the ship's force in accordance with the requirements of the contract and the manner and conditions directed by the Secretary of the Navy. The commanding officer shall afford the board every facility for the examination of the vessel and machinery and the plans and papers relating thereto; shall furnish it with all the information it may require, including lists of all defects and deficiencies that have developed, and of uncompleted and unsatisfactory work for which the contractors are responsible; and shall otherwise render it all the assistance it may require in the performance of its duties.

27. Duties of board—

The board shall carefully observe the performance of the vessel and the machinery, and upon the conclusion of the trials make a full and detailed report to the department, which shall include its conclusions on the following important points:

- (a) Whether, upon such trials, any weakness or defect in the vessel exist.
- (b) Whether the machinery or any part or parts are found to be defective in any respect; or whether there is any failure, breaking down, or deterioration, other than that due to fair wear and tear, of any part or parts of the machinery, engines, boilers, or appurtenances.

(c) What items of work required by the contract and specifications and duly authorized changes therein, that were unfinished at the time of the preliminary acceptance trial, or subsequently authorized, are, in the opinion of the board, not yet satisfactorily completed.

28. Examination after trial—

(1) As soon as practicable after these trials have been completed, a careful and thorough examination shall be made of such parts of the machinery as the board may designate as would show injury, if any occurred, or defective conditions, if any are likely to be present. This examination may be conducted by the engineer officer of the ship, in which case he shall report the result to the commanding officer, fully describing any defects or improper conditions found. The commanding officer shall forward this report, with his comments and recommendations, to the department (Board of Inspection and Survey). When such post-trial examination is made by members of the board of inspection and survey, the commanding officer of the ship shall afford all assistance and information required.

(2) Such work as may be found necessary to correct defects or deficiencies for which the contractors are held responsible shall be done at a navy yard immediately upon the conclusion of these trials.

29. (a) The report of the board that conducts the final trial shall contain work lists under the "Bureau of Construction and Repair," "Bureau of Steam Engineering," and "Bureau of Ordnance." Under each bureau the lists shall be itemized under five heads, viz:

(1) *List A.*—Items of work recommended for which the contractor is considered responsible.

(2) *List B.*—Items of work recommended for which the contractor is not considered responsible.

(3) *List C.*—Alterations recommended, contractors not responsible.

(4) *List D.*—Alterations requested and not recommended.

(5) *List E.*—Items already authorized.

(b) The board of inspection and survey shall prepare its report on sheets 8 by 10½ inches in size and shall distribute copies as follows:

Navy Department (Solicitor).....	Original.
Bureau of Construction and Repair (one to be carbon backed).....	Four copies.
Bureau of Steam Engineering.....	Two copies.
Home navy yard of vessel.....	One copy.
Commanding officer.....	One copy.
Chief of naval operations.....	One copy.
Bureau of Ordnance (of that portion of the report which refers to ordnance matters).....	One copy.

Immediately upon receipt of the above reports by the Bureau of Construction and Repair, that bureau will forward one copy each to the superintending constructor and the contractor, and upon completion of the necessary blue-print copies will forward one to the Bureau of Ordnance, one to the inspector of ordnance, and two to the home yard where the vessel is delivered, for the use of the hull and machinery divisions. Copy for the inspector of machinery will be furnished by the Bureau of Steam Engineering. One copy furnished the Bureau of Construction and Repair and one copy furnished for the use of the chief of naval operations shall be returned to the board's files after having served their purpose.

(c) The Bureau of Construction and Repair, the Bureau of Steam Engineering, and the Bureau of Ordnance shall, prior to the date of final trial, furnish the board of inspection and survey, for its information, with a statement showing:

(1) Whether or not the records of the bureau indicate that the vessel has been completed in accordance with

the terms of the contract, contract plans and specifications, and approved changes.

(2) The work authorized subsequent to the preliminary acceptance of the vessel, and whether or not the work is chargeable to the contractor.

(3) A list of the changes and alterations upon which action has been withheld pending investigation by the board that conducts the final trial.

(d) Upon receipt of copies of the report of the final trial by the superintending constructor, inspector of machinery, and the inspector of ordnance, each of these representatives shall request the comment of the contractor on the items of work under the cognizance of the bureau which he represents, for which the board considered the contractor responsible. The representatives will forward to their respective bureaus, with pertinent comment and recommendations, such statements as the contractor desires to make in regard to the items for which the board in its report considers the contractor responsible.

(e) Upon receipt by the commandant of the report of final trial he shall promptly submit separate report of estimates and recommendations to each bureau concerned, covering all items under the cognizance of the bureau contained in the report, including those for which the board considered the contractor responsible. Items for which the contractor is considered responsible will be given first consideration, and the reports covering same shall not be unduly delayed by the reports covering other items.

(f) In proceeding with authorized work, preference should be given to that for which the contractor is responsible. This work should be proceeded with immediately and carried to a prompt completion, in order that the actual cost of the work may be obtained and settlement made without unnecessary delay.

Section 5.—POST REPAIR TRIAL.

30. Object of trial—

This trial is to be made whenever the machinery of a vessel, while she has been continued in commission, has undergone extensive overhauling, repair, alteration, or materially affecting the power or capabilities of the vessel or the machinery; or whenever such machinery has undergone partial overhauling or repair, if, in the opinion of the commandant, such work has been of sufficient extent or of such character as to make such trial desirable or necessary for testing the efficiency of the work or the resulting effect upon the power or capabilities of the parts repaired or upon the vessel or machinery as a whole. Prior to completion of the repair period of any vessel, the commanding officer shall forward to the commandant recommendation as to the necessity or desirability of the post repair trial and the extent of such trial. The commandant shall advise the commanding officer as to his action and forward the commanding officer's letter for the information of the department, indicating the action by appropriate indorsement. In case the commandant disapproves the recommendation of the commanding officer, the matter shall be referred requesting the department's decision. The object of this trial is to ascertain if the work has been completely and efficiently performed; if the results sought thereby have been fully accomplished; if the machinery in all its parts is in all respects ready for service; and if the power has suffered any greater reduction than may be due to the legitimate wear the machinery has undergone since its construction and which could not be restored by the extent of the repairs undertaken. When such overhauling or repair is made while a vessel is out of commission, in commission in ordinary, or in commission in

reserve, the purposes of this trial will be accomplished by the commissioning trials described in article 22.

31. How carried out—

Post repair trials shall be held as soon as practicable after the work has been completed, the preliminary dock trials made, and the persons responsible for the efficiency of the work are satisfied that the machinery is in all respects ready for a full-power trial. The trials shall be carried out in free route, at sea, and shall be conducted by the ship's force. The conditions of the trials will be largely determined by the character of the work that has been performed in each case, and shall be conducted in such manner as the commanding officer shall deem necessary and sufficient to fully accomplish the object thereof. When the overhauling, repair, or other work which the machinery has undergone has been of sufficient extent or of such character as to make it desirable or necessary to fully test the efficiency of the work or the power or capabilities of the engines or boilers, or their appurtenances, a full-power trial of four hours' duration shall be carried out if practicable. When the machinery has undergone only a partial repair of limited extent, not affecting materially the power or capabilities of the main engines, but it is desired to test the efficiency of the work under full-power conditions, the duration of such full-power trial may be reduced to such length of time as the commanding officer, in his discretion, may deem sufficient to fully accomplish the purpose. If the repairs have been slight and the commanding officer is satisfied that they have been efficiently performed and can be sufficiently tested without a full-power trial, such trial may be dispensed with.

32. Examination after trial—

As soon as practicable after the completion of this trial such parts of the machinery as the commanding officer of the ship may deem necessary shall be disconnected and

carefully examined to determine the extent of any injury, defect, or maladjustment that shall have appeared during the trial. Any unsatisfactory conditions found shall be corrected before the work is reported completed.

33. Witnesses of trial—

Whenever repairs to the machinery of a ship in commission have been made at a navy yard, such trials as may be held upon their completion shall, if practicable, be witnessed by the engineer officer of the yard, or one of his principal assistants, together with such number of yard workmen as he may desire, to observe whether the operation of the machinery is satisfactory and the work has been efficiently performed. If such repairs are made by contract at a private shipyard, the contractors shall be permitted to have representatives on board to witness the trials for the same purpose.

34. Report of trial—

Upon the conclusion of the trial, complete and detailed report of the attending results and circumstances of the trial shall be made to the Department by the commanding officer, forwarding via the commandant.

Section 6.—LAYING UP TRIAL.

35. Object of trial—

Immediately before a ship proceeds to a navy yard to be placed out of commission, in commission in ordinary, or in commission in reserve for extensive overhauling, repair, or alteration, the vessel and her machinery shall be subjected to a full-power trial of at least one hour duration, if practicable. This trial is to demonstrate the actual condition of the vessel, especially the operating condition of the machinery, to determine the exact character of its defects, and to afford a means of judging the full extent of repairs

or alterations necessary to improve its efficiency or restore it to a condition fit for further service.

36. Witnesses of trial—

This trial shall be attended, when practicable, by the engineer officer of the yard at which the ship is about to be laid up, or by one or more of his assistants, to observe the operation of the machinery, the character of its defects and extent of repairs necessary, and to secure such detail information as will facilitate the preparation of estimates of cost of the work required.

37. When conducted by board—

If practicable, this trial shall be made in connection with an inspection of the ship by the Board of Inspection and Survey.

Section 7.—SPECIAL TRIALS.

38. When held—

Standardization, full-power, endurance, engineering competition, or other trials for special purposes, either in addition to or in substitution for any of the foregoing, may be held under such special conditions as may be prescribed from time to time by the department.

39. Detailed instructions for standardization trials—

Every naval vessel, after acceptance by the Government, whenever called upon to carry out standardization trials, shall, unless otherwise required by instructions issued by the department for special purposes, conduct such trials in accordance with the following rules:

(a) The vessel shall be weighted so as to bring her to the same draft and trim that she had on her preliminary official trial, and shall be tried over a measured course, preferably a nautical mile.

(b) The trials shall consist of a series of runs at progressive speeds for obtaining the necessary data for laying down the curves of speed on revolutions and horsepower on revolutions. Points shall be plotted on each curve cor-

responding to the maximum speed and to not less than four other speeds, at nearly equal decrements in the estimated power down to one-half the maximum speed of the vessel.

(c) Five consecutive runs, alternating in direction over the course, shall be made at the highest speed attainable under full power and at as nearly the same number of revolutions as possible to determine the highest point. At least three consecutive runs, alternating in direction and at as nearly the same number of revolutions as possible, shall be made for each one of the other points at the reduced speeds. Each series of runs at the same speed shall be uninterrupted, and shall be performed in sequence and while the tide, if any, is running in one direction. If it should be found necessary to throw out any run, a sufficient number of additional runs shall be made at that speed to produce at least three consecutive runs, alternating in direction over the course.

(d) The runs over the measured course shall be made back and forth over the same water, the vessel turning at the end of each run so as to return over the same track on the succeeding run. In the intervals between the runs the vessel shall be taken well away from the measured course, so as to insure the attainment of the required speed on the next run, and must straighten out on the compass course to be steered while at least one mile from the first range.

(e) At full power, the engines and boilers shall be worked to the utmost extent of their capabilities, not only when running the measured course but throughout the intervals between the runs; and the speed of the engines shall be so regulated that the steam pressure in the boilers will be maintained at a maximum until the whole number of consecutive runs at the highest speed is completed. The steam shall not under any circumstances be even partially shut off from the engines while off the course for the pur-

pose of obtaining a higher result while on it. In turning back at the end of the run, the helm shall not be put hard over if it can be avoided.

(f) At reduced power, the steam pressure in the boilers in use shall be maintained steady and the revolutions shall be kept as nearly constant as possible throughout the series of runs at the same speed, while off the course as well as while on it. The number of boilers to be used shall be such as to insure a steady steam pressure while working at the revolutions required.

(g) During each run over the measured course, indicator cards from each reciprocating engine, or torsion-meter readings from each turbine-driven shaft, shall be taken, and the following additional data for each run shall be collected and submitted with the report of the trial:

- (1) Elapsed time while on course.
- (2) Total revolutions of each engine while on course.
- (3) Steam pressure per gauge at main engines.
- (4) Mean effective pressures referred to the L. P. pistons for reciprocating engines.
- (5) I. H. P. or S. H. P. of main propelling engines.
- (6) Condition of bottom and time since vessel was last docked.
- (7) Trim, mean draft, and displacement.
- (8) State of sea, and direction and force of wind.

40. Determination of steaming characteristics—

The commanding officer of each newly commissioned vessel shall, from the beginning of the cruise, take advantage of every favorable opportunity to conduct trials and to obtain the steaming data necessary to determine the most economical rate of speed and the steaming radius of the vessel under varying conditions of service. Such trials shall be conducted and these qualities determined as early as practicable in the commission, and with this in view, if the vessel on being first commissioned is attached

to a fleet, squadron, or division, the commander in chief, or division or squadron commander, as the case may be, shall temporarily detach her on suitable occasions to make the necessary trials. Having once fixed upon these qualities under conditions of smooth water and comparatively clean bottom, further trials to verify the results previously obtained and to ascertain what modifications are necessary under altered conditions of wind, sea, draft, and foulness of bottom shall be made from time to time throughout the cruise as opportunities occur. Reports of the data obtained from time to time shall be made out in accordance with the prescribed forms and forwarded to the department (Operations).

41. Standardization courses—

In the absence of instructions from the department to the contrary vessels in commission in the Atlantic shall carry out standardization trials on the Rockland and Guantanamo courses only.

Section 8.—CARE AND PRESERVATION OF BOILERS AND MACHINERY.

42. Character of instructions—

The following instructions for the care and preservation of boilers and machinery relate primarily to the installations in vessels in commission. They shall be considered, however, as applying also to the boilers and machinery of steam launches and motor boats, of vessels out of commission, in ordinary, in reserve, or performing special service, and to shore stations, as far as may be consistent with the character and conditions of the service performed.

43. Protection and examination—

(1) Every part of the boilers and machinery shall be maintained in efficient working order, properly protected from undue deterioration, and, as far as possible, ready

for immediate use. All internal and external surfaces, working parts, attachments, and appurtenances of the boilers, main engines, condensers, auxiliaries, and other apparatus and appliances under the cognizance of the Bureau of Steam Engineering, shall be examined, cleaned, overhauled, adjusted, or tested at regular intervals to insure their good and efficient condition and proper preservation. These operations shall be carried out as opportunities are afforded and as nearly as practicable in accordance with a definite routine so arranged as to fulfill all the requirements of these instructions.

(2) No destroyer's machinery shall be operated at any time with higher pressures than the specified settings of the relief valve on the various parts of the machinery will allow.

44. Inspection of cylinders—

(1) As soon as practicable after each run, if the main engines are not likely to be used for a period of three weeks, the cylinders of main engines of the reciprocating type shall be opened and dried out and the walls covered with a thin coating of vaseline or cylinder oil. If, however, it should be found necessary for any other purpose to open any such cylinders after a run, and unless it is expected that the engines will be used again within three days, then such cylinders as it may be necessary to open shall be dried out and coated with vaseline or cylinder oil. In any case all air inlets, such as drains, indicator connections, etc., whereby air might be admitted into the cylinders, shall be kept tightly closed while the engines are lying idle.

(2) The interiors of the cylinders and the piston nuts, rings, springs, followers and follower bolts of main engines of the reciprocating type shall be examined after each run when they have been worked at or above two-thirds of their designed full power, and also at intervals of not

more than thirty steaming days when worked at lower powers.

Engines to be jacked daily—

(3) When not under steam main engines of the reciprocating type shall be turned at least one complete revolution every day when possible, and the main valves and links moved through their full travel.

45. Lifting turbine casings—

(1) The casings of turbine engines shall be lifted and their interiors examined at intervals which shall not exceed two years. To this end, as far as practicable, the casings of one-half of the turbines installed shall be lifted each year. Whenever this is done advantage shall be taken of such opportunity as may be presented at that time to observe the condition of all nozzles, blading, packing rings, and other internal working parts. When practicable, such examination shall be made when the vessel is where adequate facilities are available for such necessary repairs as may be found beyond the capacity of the ship's force. The commanding officer shall make a special report to the department (Operations) on the condition of the turbines as disclosed by each such examination, which report shall also refer to the date of the last preceding examination and report.

Interiors of idle turbines to be kept dry—

(2) To reduce to a minimum the corrosion of the interior surfaces of turbine casings and rotors it is of the utmost importance that their interior spaces be kept thoroughly dry while the turbines are not in operation. To this end, after securing the main turbines the main air pumps shall be continued in use, maintaining a moderate vacuum until the turbine casings have cooled down to approximately the temperature of the engine room. When it is expected that main turbines will not be required for use again under steam within forty-eight hours, the main air

pumps shall be employed daily for a few minutes to produce a moderate vacuum in their interior spaces for drying them out.

46. Auxiliary machinery—

All auxiliary steam machinery not in frequent use shall be moved by hand every day, when possible, and by steam at least once each week.

47. Machinery securities—

All holding-down bolts, chocks, and ties fitted to the engines, boilers, and other parts of the machinery to prevent them from shifting shall be examined frequently and kept in efficient condition. They shall be carefully tested by sounding or other suitable means to insure their reliability for their particular purposes at least once in three months.

48. Cold weather—

Care shall be taken during cold weather to prevent damage being done by freezing to any parts of the boilers, machinery, or fittings containing water. To this end the temperature of compartments containing such parts shall be kept above 40° F., if possible.

49. Joints—

All joints, valves, and cocks of the steam pressure and exhaust piping, of the feed suction and delivery systems, and of the condensers and feed tanks, by which water may be lost or the vacuum impaired by leakage, shall be examined frequently and kept tight.

50. Glands and packing—

The packing of the glands of all piston rods and valve stems must be adjusted with great care to avoid leakage. Particular attention shall be given to those connected with low-pressure cylinders and other parts working below the atmospheric pressure to prevent not only loss of vacuum but the admission of air to the feed system.

51. Condensers—

(1) Every effort shall be made to keep the condensers tight and to prevent the leakage of salt water to the feed system. Whenever the tubes of condensers are found to be leaking, steps shall be taken without delay to locate and stop such leak and prevent the admission of salt water to the boilers. Care shall be taken to prevent water accumulating in the condensers and overflowing into the cylinders of the engines.

Condenser-tube packing—

(2) Care must be taken that the condenser-tube glands fit tight in the threads and are screwed into the tube sheets to a sufficient depth to insure against backing out. For this reason too much tube packing must be avoided.

Condenser tubes—

(3) The tubes of surface condensers shall be examined at least once in six months and kept clean. If considerable steaming is done, they shall be examined at more frequent intervals. When the tubes and other interior surfaces are found coated with grease, this may be removed by boiling them with a solution of soda. Specimen tubes from different parts of each condenser shall be drawn from time to time and examined to ascertain their condition. An early indication of deterioration is brittleness, and when this state is indicated they must thereafter be watched very carefully and a special report shall be made describing their condition. Timely requisitions shall be prepared to insure having a sufficient supply of new tubes at hand when partial or complete renewal becomes necessary.

52. Feed pumps—

(1) The boiler feed pumps shall not be used for other purposes than those connected with the service of the boilers or feed water, except in cases of emergency; and when not under steam their pistons and valve gear shall be moved every day.

Combined feed and fire and bilge systems—

(2) In some vessels pumps have been fitted for use either as auxiliary feed pumps or as fire and bilge pumps. In such cases, in order to avoid the possibility either of admitting salt water to the boilers or of wasting feed water, those pumps regularly used as feed pumps shall have all valves of the salt-water connections wired shut, and those pumps regularly used as fire and bilge pumps shall have all valves of the feed-water connections wired shut, the wiring being removed only in cases of emergency and urgent necessity, or for purposes of examination and test not more frequently than once a quarter.

53. Evaporators—

The interiors of the evaporators shall be examined, and the tubes or coils cleaned and scaled at as frequent intervals as practicable. All relief valves, gauges, cocks, and other fittings shall be kept in thoroughly efficient condition, and the openings in the shells and pipes connecting them with the interiors shall not be allowed to become choked. Upon the completion of scaling or general overhauling of an evaporator, all parts subject to the pressure of the primary steam shall, if practicable, be tested by steam to insure their tightness. When an evaporator will not be required for use for several days, the shell and coils or tubes shall be drained and kept dry till needed for service.

54. Zinc protectors in condensers, etc.—

Zinc protectors shall be fitted in the water heads of the condensers and in the feed tanks, evaporators, water cylinders of pumps, ice-machine coolers, and all copper suction and discharge pipes designed to convey salt water, in a manner approved by the Bureau of Steam Engineering and shown on the official drawings. They shall be examined from time to time, scaled and refitted to keep them effective and renewed when they become much deteriorated.

55. Indicators—

Care shall be taken to preserve the indicators in a clean and efficient state and free from any corrosion or deterioration. They shall not be allowed to remain attached to cylinders when not required for immediate use, and shall be carefully dried and cleaned and lightly coated with cylinder oil before being put away.

56. Machine tools, etc.—

All machines, tools, instruments, and other appliances and fittings supplied for the engineer's workshop or for general use shall be kept in good order and thoroughly efficient.

57. Hydraulic machinery—

(1) The hydraulic pumps, engines, pipes, and the gear connected therewith shall be examined frequently, kept in good order and clear of water when not being worked.

(2) The hydraulic engines shall be moved at least twice a month by means of the pumps fitted for the purpose, to prevent the rams becoming set and to insure their efficiency.

(3) When water necessarily remains in the pipes, the air cocks shall be left open and care shall be taken to prevent freezing.

58. Compressed-air systems—

In compressed-air systems great care must be taken to keep the air suction strainers and air passages of the compressors from becoming choked, the reversing valve motion correctly adjusted, the steam and air piston packing rings, piston-rod stuffing-box packings, and air inlet and discharge valves correctly fitted and tight, and especially all joints, fittings, and connections of the external pressure system perfectly tight to prevent waste of the compressed air by leakage. Owing to the small clearances, great care must be taken in adjusting the bearings of the compressors. All parts of the system subject to pressure shall be tested to the full pressure at least once a year. The air cylin-

ders and their passages shall be thoroughly cleaned at frequent intervals by circulating through them a hot solution of lye or soda, followed by a thorough rinsing with hot fresh water, and finally a light coating of oil on the cylinder wearing surfaces.

59. Idle boilers—

(1) Boilers when not under steam or open for examination shall be kept quite full of fresh water made slightly alkaline. They shall be pumped full within twenty-four hours of completion of steaming and shall be so kept until within twenty-four hours of again raising steam. Even if the boiler is to be examined within a few days of completion of steaming, the water shall not be allowed to remain at working height, but the boiler shall be pumped full.

Alternative method—

(2) When it is not practicable to keep boilers full of fresh water and, generally, when it is known that certain boilers will be kept idle for a considerable length of time, they shall be emptied and their interiors shall be thoroughly dried out. Open trays of as large capacity as practicable and filled to about half their height with quicklime shall be introduced through the manholes into the upper and lower parts of each boiler. They shall then be closed air-tight, and special precautions shall be taken to prevent any moisture entering the interiors while they are being thus treated. If necessary, joints of the feed and blow systems shall be broken, and adjacent sections of steam piping shall be shut off and their drains left open.

Boilers open for work—

(3) Whenever the boilers are open for cleaning and overhauling, their interiors shall not be allowed to remain in a damp condition longer than required to accomplish the necessary cleaning. The cleaning and washing out of the interiors shall be completed as soon as possible after opening, and then the boilers shall be closed at once and filled.

If, in order to complete repairs or overhauling of the internal fittings, it is necessary to keep the boilers open for a considerable time after they have been washed out, their interiors shall be thoroughly dried out and kept dry until they can be closed and filled.

Fire sides of boilers—

(4) To prevent corrosion while exposed to the atmosphere, especially during periods of wet weather, the fire sides of the tubes and other heating surfaces, fittings, and parts within the furnaces, combustion spaces and uptakes of idle boilers must be kept free from moisture. Light fires in small stoves or pans placed in the furnaces or ash pits may be used to dry out empty or idle boilers.

Furnace doors, etc.—

(5) The furnace and ash-pit doors and the dampers in the uptakes of all idle boilers shall be kept closed. The furnaces of empty boilers shall not be primed. When practicable, the funnels and escape pipes shall be kept covered when all of the boilers connecting to them are idle.

(6) Whenever water-tube boilers of the express type (Normand, Thornycroft, Yarrow, White-Forster, etc.) are not to be used for a considerable period of time, they shall be laid up as prescribed in paragraph (2) of this article. In addition to the precautions stated, the fire sides of such boilers shall be thoroughly cleaned and wire brushed and the *fire side* of the tubes where they enter the tube sheets of the lower drums shall be sprayed with fuel oil for preservation.

60. Zincks in boilers—

(1) In boilers in which zincks are fitted clean plates of rolled zinc only shall be used, and they shall be of the standard dimensions of twelve by six inches by one-half inch thick, or of dimensions that may be cut from such standard plates with the minimum of loss. Worn or

defective zinc scrap shall not be recast for such use. When practicable, they shall be fitted in suitable baskets to catch detached pieces should they become disintegrated. Special care shall be taken to insure proper metallic contact between the zinc plates and the stays, lugs, or plates of the boilers to which they are attached. All surfaces and points of contact shall be made bright and shall be firmly bolted together.

(2) The zincs shall be carefully examined at each inspection of the interiors of the boilers. Should they be found considerably oxidized they shall be scaled and refitted, or replaced by new plates if much deteriorated. Plates that have become bent or distorted shall be removed at once as inefficient.

(3) Zincs in boilers in which boiler compound is employed are so quickly disintegrated that, even if corrosion were prevented by their use, it is doubtful that the cost and labor of installation would be warranted. Zincs and zinc baskets will, therefore, be removed from all boilers in which compound is used. On auxiliary vessels not manned by naval crews, and on yard craft, boiler compound shall not be used; zincs will be used in the boilers of these vessels as directed in paragraphs (1) and (2) of this article.

61. Precautions when men are to enter boilers—

(1) The steam stop valves, feed and blow valves, and any other valves or cocks by which steam or hot water could enter boilers in which men are to work, shall be shut and secured so that they can not accidentally open or be opened. The engineer officer on duty shall see that these precautions are taken before he allows any men to enter the boilers.

Precautions in opening boilers—

(2) Before removing any fittings or parts subject to pressure or taking off the manhole plates of a boiler after it has been under steam, steps shall be taken to insure a

complete absence of pressure by opening the air cock and the test and water gauge cocks connecting with the steam space. Whenever boilers are opened they shall be ventilated for a sufficient time to allow all foul air to escape and no one shall be allowed to enter them until the purity of the air has been ascertained. The possibility of an explosive mixture of hydrogen and air being present when boilers, evaporators, etc., protected by zinc, are opened shall be borne in mind, and steps shall be taken to diffuse the air contained in them before applying an open light.

62. Deposits in boilers—

(1) Great care shall be taken to keep the interiors of the boilers, particularly those of water-tube type, as free as possible from all deposits and from grease or other foreign matter in suspension. Deposits of scale, grease, or other matter adhering to the heating surfaces, and loose scale or other solid substance lodging in the tubes, besides reducing the evaporating efficiency, are liable to cause overheating and serious injury. Grease and other foreign matter in suspension in the water, even though they may not seriously foul the heating surfaces or restrict the circulation, tend to produce priming and diminish the production of steam and to aid the various processes of corrosion to which the interiors are particularly subject.

Oil and salt water in boilers—

(2) No tallow or oil of vegetable or animal origin shall be allowed to enter the boilers. Salt water shall never be introduced into the boilers except for the purpose of washing out their interiors, and whenever it is used for this purpose the boilers shall afterwards be drained and rinsed out with fresh water and then thoroughly dried, if required to remain open, or closed and filled with fresh water immediately thereafter.

Fresh water for boilers—

(3) The boilers shall always be filled with fresh water of as pure quality as can be obtained.

Changing water in boilers—

(4) The water shall be retained in the boilers without change as long as practicable, whether they be steaming or idle. Idle boilers shall not be used for trimming ship nor as reservoirs for storing any other water than that intended for steaming purposes. They shall be run down or emptied only when necessary for examination, cleaning, or overhauling, and the water changed only when it has become unfit for further use by reason of being dirty, acid, or salt. Water may, however, be used from fire-tube boilers for purposes of make-up feed, if necessary, when no other fresh water is available when steaming and none can be supplied by the evaporators; but when this is done the water line in the boilers from which such water is taken must not be left at a level among the tubes, and they must be pumped full again as soon as a sufficient supply of fresh water can be obtained.

Feed water to be pure—

(5) The feed water shall be maintained as free as possible from impurities, of which the most injurious are sea water, air, and grease. This requires most careful attention to all parts of the entire machinery plant through which the boiler water ever passes, either in the form of steam or water. All devices provided for removing air and grease from the feed water shall be habitually used and shall be kept in the most efficient condition possible. All leaks shall be eliminated from the boilers, piping, glands, condensers, feed tanks, pumps, and from the entire system generally, and the quantity of make-up feed water required reduced to a minimum thereby. Water distilled from sea water is liable to be actively corrosive, hence the importance of reducing the amount of make-up feed to a minimum.

63. Tests for alkalinity and salinity—

(1) The water in all boilers under steam and in the main feed tanks shall be tested daily for alkalinity and salinity. The water in boilers not under steam shall be so tested weekly. The water in the feed tanks shall be examined every watch while under way, and every effort shall be made to promptly discover any salt-water leaks that may develop in the condensers. In making the salinity test by the method of determining the quantity of chlorine present, it must be borne in mind that to obtain correct results the sample of water being tested must first be made neutral or very slightly alkaline, and reagents used for this purpose must not contain chlorine.

Tests for corrosive properties.

(2) In addition to the tests required by paragraph (1) the water in each boiler shall be tested once each week for corrosive properties in the following manner: A small piece of clean, bright boiler steel shall be suspended in a clear glass bottle filled with water as drawn from the boiler. If, after twenty-four hours, the piece of steel shows no signs of discoloration or of formation of rust spots, and if the water does not become discolored, the boiler water shall be considered noncorrosive.

64. Use of boiler compound, etc.—

(1) Navy standard boiler compound shall be used in the boilers of all vessels, except auxiliary vessels not manned by naval crews and yard craft, only in sufficient quantity to insure that the water in the boilers is not acid. The alkaline strength of the boiler water shall be kept as low as possible, but shall never be allowed to exceed one-half of one per cent of normal alkaline strength.

(2) If Navy standard boiler compound is not used when obtainable, or is not used in the prescribed amounts, the fact shall be reported to the Bureau of Steam Engineering

and the report shall state in detail the reasons therefor. Whenever the Navy standard boiler compound is not obtainable the water in boilers shall be maintained slightly alkaline by the use of sal soda or lime. As when using boiler compound, this alkaline strength shall never be allowed to exceed one-half of one per cent of normal.

(3) On auxiliary vessels not manned by naval crews and on yard craft Navy standard boiler compound shall not be used. On all such vessels the boiler water shall be maintained slightly alkaline by the use of sal soda; this alkaline strength shall be just sufficient to insure that the boiler water is never acid. To this end only the smallest quantity of sal soda possible to accomplish the purpose intended shall be used.

(4) When boilers are being filled with new water, the boiler compound or sal soda should be dissolved in fresh water and the solution put into the boiler in the most direct manner. In the case of closed boilers compound should be added in the most direct practicable manner in amounts shown necessary by analysis of the water.

(5) As lime is not entirely soluble in water, it shall never be added directly to the feed water or boiler water. Unslacked lime, when used, shall be dissolved as far as possible in cold fresh water and allowed to stand for some time in a closed vessel, until the insoluble putty has settled. When the solution is clear, it may be decanted and added to the feed water or boiler water as required. Unslacked lime shall be supplied in air-tight tins, and it is absolutely essential that it shall not be left exposed to the air longer than necessary, as it possesses a great affinity for, and readily absorbs, carbonic-acid gas.

65. Inspection of boilers by engineer officer—

(1) The engineer officer shall keep himself fully acquainted with the general condition of the interiors of the boilers and shall satisfy himself, by periodic inspection

and by regularly testing the quality of the water, that no material deposits are present, and that the water is maintained in as clean and pure condition as possible and of the prescribed alkaline strength.

Precautions as to keeping boilers clean—

(2) Whenever there may be reason to believe that deposits may be present in the boilers, they shall be cleaned out at the first available opportunity. It must be borne in mind that boilers which contain deposits on their heating surfaces or have grease or other foreign matter in suspension in the water are not in a safe condition for steaming, and it is particularly important that in such circumstances forced draft should not be used except in case of great emergency.

Frequency of overhauling—

(3) The length of time boilers may be used under steam before requiring to be cleaned out and overhauled depends upon various circumstances with regard to their type and present state of preservation, the particular requirements of the service for which they are used, and the general character and influence of the local conditions under which they are operated. The engineer officer, knowing the particular circumstances under which the boilers in his charge are used, shall be guided by these circumstances in determining the frequency with which it is necessary and practicable to clean and overhaul them. He shall report to the commanding officer whenever he considers it necessary or advisable to open the boilers for examination or cleaning.

(4) Experience with water-tube boilers in vessels in commission shows that, under the usual conditions of operation, the interiors of such boilers should be completely or partially cleaned and overhauled, as found necessary by examination, after having been used under steam for any purpose for a total of about seven hundred hours since the previous cleaning. In special cases, where the

general conditions of operation are particularly favorable, this period may sometimes be extended to one thousand hours. When the operating conditions are not good, however, the boilers shall be opened at more frequent intervals, examined to obtain an assurance of the condition of their interiors, and cleaned, if necessary.

66. Procedure in overhauling—

Whenever a boiler is laid up for a complete cleaning and overhauling, the following general operations and procedure shall be carried out:

- (a) Clean fire side and overhaul all furnace fittings, brickwork, baffling, and fire parts.
- (b) Empty, open, and wash out the interior of the water spaces.
- (c) Clean and inspect the water side and overhaul zincs and internal fittings.
- (d) Rinse out and close the boiler.
- (e) Overhaul all valves, gauges, cocks, and other external fittings.
- (f) Examine and repair, as required, all parts of the lagging, casing, and seating.
- (g) Apply hydrostatic test for tightness of valves, gaskets, etc. (See article 77 (2)).
- (h) Test for tightness under steam, including tightness of casing, and adjust safety valves.

67. Solid matter in boilers—

Loose scale or other solid matter in water-tube boilers is extremely dangerous to their safety, and when cleaning the interiors of such boilers, careful examination shall be made before closing them to insure the absence of loose or detachable scale, disintegrated zinc, or other foreign matter from the tubes and from all other parts of the interiors.

68. Cleaning boilers after steaming—

(1) As soon as practicable after the completion of each period of steaming, the ashes and soot shall be removed from the furnaces, ash pans, combustion spaces, tubes, and uptakes, and all accessible parts exposed to fire shall be thoroughly cleaned and overhauled.

(2) Whenever practicable, the tubes shall be cleaned as thoroughly as possible with the air or steam tube cleaners shortly before the fires die out. Otherwise, if the soot be allowed to remain and cool down with the tubes, it is liable to form a scale which will be difficult to remove afterwards.

(3) The steam tube cleaners shall not be used in the boilers except when the fires are lighted.

69. Examination of boiler tubes—

(1) The boiler tubes shall be examined frequently on the fire side. In water-tube boilers of the straight-tube type the lower rows in the furnaces shall be carefully watched and shall be tested frequently by a straightedge or other means to detect excessive deflection. Deflection and swelling of tubes are signs of overheating, and when either state is observed the interior condition of tubes so affected shall be investigated. Internal fouling sufficient to interfere with circulation or proper heat transmission will cause overheating and result in distortion of some kind. Swelling of tubes can always be detected by passing a gauge over them, and very often by hand. Bulged or blistered tubes shall always be renewed. Straight tubes found deflected more than three-quarters of an inch shall be renewed.

Tube ends flared—

(2) All tubes of water-tube boilers, except Field tubes, shall be flared at the ends to prevent them from pulling out of the tube plates or headers. The tubes shall extend through the holes in the plates or headers not less than

three-sixteenths of an inch, and flaring shall be accomplished to such an extent that the outside diameter of the flare is made materially greater than the hole into which the tube is expanded.

Tubes with worn ends—

(3) In examining water-tube boilers, especially those of small bent-tube type, in which, owing to the shape of the tubes, the pressure tends to force the tubes out of the plates, particular attention shall be paid to the attachment of the ends of the tubes. When the projecting end of a tube becomes worn away to such an extent that the wear extends into the rolled part of the tube, or when it becomes materially thinned in the rolled part, it shall be renewed.

Precautions in renewing tubes—

(4) When renewing tubes that are secured by expanding, each tube hole shall be carefully examined to see that it is truly cylindrical and to the correct diameter. After the expanding is done, each tube end shall be inspected to see not only that it has been well done on the inside, but also that it is expanded close to the edge of the hole on the outside.

70. Exterior parts of boilers—

(1) The fronts, backs, bottoms, casings, and other exterior parts of the boilers shall be kept free from scale and rust and from contact with ashes; they shall be kept well protected with paint and as clean and dry as possible. The tops of the casings shall be properly protected against corrosion caused by drippings from air cocks, stop valves, or other sources. The spaces at the backs and sides of the boilers shall be kept clear, to allow access to all parts, and nothing wet or combustible shall be stowed over or around them. The use of hose for washing down the exteriors of the boilers or the bulkheads above the floor plates shall not be allowed.

(2) The uptake casings of the boilers shall be kept clean and well painted. The air spaces between the uptakes and their casings shall be examined frequently and any accumulation of dirt therein prevented.

(3) The air ducts and casings of forced draft systems shall be kept free from ashes and rust and well painted.

(4) The funnel guys shall be frequently examined and adjusted, and their turnbuckles kept oiled and in good condition.

(5) The bilges in the firerooms shall be kept dry and well painted.

(6) When it is necessary to keep ashes in the firerooms until a lighter can be obtained they shall not be stowed against any part of the boilers or bulkheads. Boards or heavy canvas shall be used to protect the metal surfaces.

(7) Cotton waste or other materials used for wiping, which have become wet with oil, shall be cleaned or destroyed immediately after using, or shall be put in a covered fireproof receptacle and kept in a safe place until they can be so disposed of.

71. Engine and fireroom gratings—

The gratings over the engine room and fireroom hatches shall not be taken off except in cases of necessity, and shall then be replaced as soon as possible. No material of any kind shall be stowed on or over these gratings, whereby the ventilation may be obstructed or anything may fall through and cause injury to the machinery or the personnel in the compartments below.

72. Condition of boilers to be logged—

All parts of the boilers shall be carefully examined whenever they are exposed for cleaning and overhauling and their conditions as found upon these examinations shall be described in the steam log. Should unusual cases of damage or deterioration be discovered at any time special report shall be made to the Bureau of Steam

Engineering, stating in detail the extent of injury sustained, the remedies applied, and, as far as can be determined, the causes.

73. Reduction of pressure—

Should the engineer officer at any time consider it necessary or advisable to reduce the load on the safety valves of the boilers he shall report his opinion to the commanding officer, with his reasons. If the commanding officer concurs in such opinion, a survey shall be held by a board of not less than two commissioned line officers for the purpose of determining the necessity for the reduction of the load and the amount thereof. Upon approval of the recommendation of the board by the senior officer present the load shall then be reduced in accordance with such recommendation if found to be necessary or advisable. The amount of the reduction, the reasons for making it, and the load to which the safety valves are then set shall be noted in the steam log and reported to the Bureau of Steam Engineering. The load on the safety valves shall not be increased without the authority of the Bureau of Steam Engineering.

74. Safety valves—

The hand gear for lifting the safety valves shall be thoroughly examined at least once each week, whether the boilers are steaming or idle. Whenever steam is raised in any boiler, the safety valves shall be tested by steam and adjusted as necessary to lift at the prescribed pressure. The hand gear shall also be tested at the same time to insure its being in proper working order. These tests of the safety valves and of the hand gear shall be repeated once each week while the boiler is under steam. If the safety valves of any boiler can not be adjusted to lift properly at the prescribed pressure under steam, fires shall be hauled from it and it shall not be used for steaming until the fault has been corrected. A special report shall

be made to the Bureau of Steam Engineering in every case where safety valves fail to operate properly. All tests of safety valves shall be recorded in the steam log.

75. Boiler fittings—

(1) All valves, attachments, and fittings of the boilers shall be thoroughly overhauled at regular intervals and kept in efficient working condition.

(2) All water-gauge fittings must be kept in thoroughly efficient condition. Great care shall be taken to insure that only glasses of proper quality and dimensions are used, that they are correctly fitted in place, and that all cocks and fittings connected with them are examined frequently and kept in proper order.

(3) Boiler steam gauges shall be compared with a standard gauge at least once a quarter, and adjusted to agree with the standard at the working pressure of steam.

76. Worn boilers—

Whenever there may be reason to believe that any parts of the main structure of the boilers that are subject to pressure and that involve their safety, except the tubes, are unduly worn or corroded, such parts shall be drilled and their thickness measured. The holes shall not be more than one-half inch in diameter, and afterwards shall be tapped and filled with screw plugs securely riveted over to prevent leakage. The thickness of the parts originally and when thus tested, the probable cause of the corrosion or wear indicated, and all other details of the test shall be entered in the steam log and the engineer officer's record book. The exact position of the holes drilled for this purpose shall be marked on the drawings or otherwise shown by sketches for future reference and identification.

77. Water-pressure tests—

(1) The boilers shall be tested by water pressure at such times as the engineer officer may deem necessary or advisable.

(2) Whenever such test is made to prove the safe strength or the tightness of any riveted, expanded, or other permanent structural joints or parts of a boiler, the following method shall be employed: The water shall be heated to a temperature of not less than 150° F.; and, before applying pressure the boiler shall be completely filled with water and entirely free from air, and necessary precautions shall be taken to insure that there be no leak past the main or auxiliary stop valves into pipes that may contain steam. The pressure to be applied shall not exceed one and one-quarter times the authorized safety valve setting unless special directions from the Navy Department Commander in Chief, or senior officer present are received. For ordinary overhaul of boilers, referred to in Article 66, the hydrostatic pressure described and outlined in "Instructions for care, preservation, and operation of boilers" will be used, as it is not advisable to subject boilers to unnecessary strains except for special reasons. In the case of fire-tube boilers that have been in service longer than two years, the water pressure to be applied shall be limited to twenty-five per cent greater than the load on the safety valves. The pressure shall be increased slowly and be very carefully applied, in order that injury may not be caused by over-pressure, particularly if a drill test should have revealed unusual thinness of any parts.

(3) During the application of the water pressure, the boilers shall be carefully examined and proper gauges used, when practicable, to detect any change in form in any of their parts. Should any indications of probable permanent deformation be observed, the test shall cease, and the weak parts shall be strengthened as necessary. If this be not practicable, a new test pressure twenty pounds below that at which permanent deformation commenced shall be adopted, and the new working pressure shall be that which corresponds to such new test pressure according to para-

graph (2). The load on the safety valves shall be reduced to the new working pressure.

78. Tightness of valves, etc., under working pressure—

To prove the tightness of all valves, gaskets, and fittings of boilers under the working pressure, the following test shall be made, if practicable, upon the completion of each general overhauling or repair affecting such parts. A water pressure of ten pounds per square inch less than the load on the safety valves shall be applied. After attaining this pressure all connections, including the feed, stop, and check valves, shall be closed and the drop in pressure during a considerable number of hours noted. If the test be made with water of nearly the same temperature as the boiler and the fireroom, the drop in pressure should not exceed twenty pounds in twenty-four hours. If there is no leaks in the boiler or its fittings, there will be no change in the boiler pressure other than that due to change in temperature of the boiler or the water, or both. It shall be borne in mind that leaky feed valves will give false indications and that, until gaskets are softened by heat, there may be slight leaks around the plates, which will readily take up under steam pressure. For the latter reason, whenever sufficient time is available, this test should be made after steam has been raised to adjust the safety valves and the boiler has again cooled down, when this is done in connection with general overhauling. Although hot water searches out leaks with more facility than cold water, the time element included in this test affords opportunity for the water to cool, with consequent contraction in volume and reduction in pressure, giving an appearance of leaks that may not exist. For this reason water used for this test should be as nearly as possible the temperature of the boiler and of the fireroom.

79. Precautions with internal-combustion engines—

(1) No smoking, naked lights, or electric apparatus liable to spark shall be permitted in the vicinity of vaporizers,

cylinders, or crank chambers of internal-combustion engines when any of these parts are open for examination or overhauling.

(2) Pistons, valves, cylinders, and vaporizers of internal-combustion engines shall be frequently examined and cleaned, and all moving parts and wearing surfaces shall be kept thoroughly lubricated and in good condition. The pistons and valves shall be kept tight, in order that the efficiency of the engine may not be impaired by leakage of air during compression.

80. Torpedo-boat engines—

Owing to the lightness of construction and high speeds at which torpedo-boat engines run, increased care is necessary in attending to and adjusting the various working parts. When setting up the brasses of connecting rods, the amount of clearance left at each end of the cylinders shall be accurately measured to see that it coincides with the original clearance. The leads of the valves shall be carefully measured, to determine the necessary readjustment through wearing down of the eccentrics or valve gear. All joints, especially those of the steam pipes, are subject to injury from vibration. The main steam pipes, and any other pipes which appear to suffer in this way, should be tested from time to time to discover any defects arising from this cause.

81. Machinery of steam launches—

Unless it is expected that the machinery of steam launches will be used again in a few days, the wearing surfaces of cylinders and valve chests shall be cleaned and lightly coated with mineral oil, and the engines made ready for use. All drain cocks shall be left open, and the engines, valves, pumps, etc., shall be moved every day. Strainers on the sea-valve openings shall be kept clear, and receiving pipes of circulating and air pumps examined and cleaned annually, or more frequently if necessary. The boilers of steam launches shall be frequently examined, internally

and externally, and special attention shall be paid to the furnace. Salt water shall not be used in these boilers except in cases of great emergency when no fresh water is available, and after its use they shall be scaled and cleaned as soon as possible. The safety valves shall be examined whenever steam is raised after an interval of more than seven days not under steam. The condition of the safety valves, water gauges, check valves, etc., shall be ascertained from time to time while the machinery is working. Great care shall be taken to keep these important fittings in a thoroughly efficient condition.

82. Docking ship—

Whenever a vessel is docked, a careful examination shall be made by the yard force of the outboard portions of the shafting, couplings, and propellers. This examination shall be made as soon as practicable after docking, and any defects observed shall be reported at once so that the necessary action may be taken without delaying the undocking of the vessel. The wear of the lignum-vitæ, both in the stern tubes and the strut bearings, shall be ascertained and recorded. Bronze and Monel metal propellers shall be cleaned and polished. In the case of turbine-driven destroyers, when a clearance of $\frac{1}{16}$ inch is reached in the outboard shaft bearings, the lignum-vitæ shall be renewed. The original clearance shall not be allowed to exceed $\frac{3}{2}$ inch.

83. Ships going out of commission—

(1) When a ship is ordered out of commission, the iron or steel bright work of the machinery, except such parts as pass through stuffing boxes, or upon sliding surfaces (as piston rods, valve stems, slide and guide faces, and journals), shall be covered with white lead and tallow.

(2) Metallic packing shall not be removed from piston rods or valve stems, but all vegetable or fibrous packing shall be removed.

(3) All parts passing through stuffing boxes or working upon their surfaces, such as piston rods, valve stems, guide and slide faces, clutch coupling slides, interiors of steam cylinders, and valve chests, must be cleaned and covered with a coating of vaseline, the machinery being moved after first application so as to bring all these parts upon properly covered surfaces.

(4) All bearings shall be well oiled and the oil holes plugged with waste, the engines being turned one complete revolution after oiling.

(5) All water-containing parts of the machinery inside of outboard valves shall be thoroughly drained. Particular attention shall be paid to draining the pump cylinders, condensers, feed, blow, and suction pipes; fire main, and all steam and exhaust piping where it is possible for water to gather. In draining these pipes, flange joints shall be broken at the lowest parts of each system and wherever a pocket is formed which is not drained by a proper drain pipe. Where possible, outboard valve casings below valve seats shall be covered with nonconducting material, such as sawdust or manure, temporarily boxed in, and the interiors of the casings below the seats filled with heavy oil, injected, if practicable, through the steam connection, to displace the water.

(6) The gauges and oil cups shall not be removed.

(7) The sea valves shall be closed and properly secured.

(8) The storerooms shall be cleaned.

Section 9.—OPERATION AND MANAGEMENT OF BOILERS AND MACHINERY.

84. Character of instructions—

The following instructions relate especially to such matters as are essential in the operation of the boilers and machinery to prevent injury, to insure their safety, and to secure the most efficient and economical performance.

They shall be considered to apply to the same extent as the instructions contained in section 8.

85. Cylinders—

(1) The cylinders, receivers, and steam jackets of all engines shall be gradually and thoroughly heated before steam of full pressure is admitted to them. Whenever practicable the connections between the boilers and main engines shall be opened as soon as fires are lighted to allow the hot air and steam as it rises to circulate through the engines and warm them gradually.

(2) Water must not be allowed to accumulate in the receivers or jackets of engines, but care shall be taken that steam is not blown through the traps and wasted while the engines are working.

Warming up turbines—

(3) Thorough and even warming up of turbines is absolutely necessary so that all parts will expand uniformly; this can only be accomplished when rotors are moving in order that the steam may come in contact with all parts. To this end it is essential that the rotor should be revolved as soon as steam is admitted to the turbine, as otherwise local distortions will be caused. In no case shall the rotor of any turbine be permitted to stand idle during the warming-up period. While warming up a low vacuum should be maintained, merely sufficient to keep the turbine clear of water and to permit the steam to be evenly distributed throughout the turbine. The auxiliary exhaust shall never be turned into a turbine until it is thoroughly warmed up and in operation. When standing by, turbines should be turned a few revolutions by steam at least once each half hour.

86. Water rams—

The greatest care should be exercised to guard against water rams by carefully draining all pipes or other spaces where any water might accumulate before steam is ad-

mitted to them. In opening the valves connecting the boilers to the steam pipes or in connecting different sections of steam piping, the by-pass valves, if fitted, shall be opened first, and the pipes warmed and the pressure equalized before the large valves are opened. The drains shall be kept open until it is certain that the pipes are entirely free of water.

87. Air and circulating pumps—

Independent air and circulating pumps shall be started at least fifteen minutes before attempting to move the engines, or to warm them by admitting steam to the cylinders through the by-pass valves or otherwise.

88. Telegraphs, etc.—

The engine telegraphs and other instruments fitted for transmitting signals to and from the engine rooms shall be carefully examined and tried before getting underway.

89. Rate of expansion—

(1) Modern reciprocating engines are designed to carry out the principle of expansion to its utmost practical limits, and, in order to attain the greatest economy, especially when working at reduced speeds, every means fitted shall be utilized to secure the highest possible ratio of expansion of which the engines are capable. To this end the engineer officer shall ascertain the most efficient rates of expansion at all powers and the corresponding points of cut-off and other particulars of adjustment. These particulars together with related data, shall be carefully recorded so that they may be readily utilized when changes in speed or power are required.

(2) In the design of modern reciprocating engines, the cylinder ratios and the details of the valve motions are calculated to fix the ratios of expansion throughout the whole engine required to obtain the best practical economy when working at full power. To provide for varying to some extent the ratio of expansion of the engines as a whole, and

of the several cylinders, particularly when working at reduced powers, in order to secure the most advantageous expansion and distribution of work in the several stages of expansion, the links are suspended from adjustable blocks by means of which the point of cut-off and consequently the ratio of expansion in the several cylinders may be varied within small limits. However in those engines where the lowest stage of expansion is carried out in two cylinders of equal size instead of in a single cylinder, the design does not contemplate the total work of the whole engine being divided equally between all of the cylinders, but rather an approximate equality between the several stages of expansion. It should be borne in mind that the total ratio of expansion throughout the engine may be changed by altering the cut-off for the high-pressure cylinder only, and that any alteration of the cut-offs for the other cylinders merely affects the distribution of work between the several stages of expansion, and this only by relatively small amounts.

(3) It is not anticipated that, in effecting the greatest change of ratio of expansion possible within the scope of the adjustable cut-off block for the high pressure cylinder, any inequality of distribution of work produced would interfere with the smooth working of the engine, if the bearings are in good condition and properly fitted. The practice, therefore, of distributing the work equally in each cylinder or stage of expansion shall be considered as of only secondary importance.

90. Internal lubrication of cylinders—

(1) No tallow or oil of vegetable or animal origin shall be used for the interior lubrication of the steam cylinders and valve chests, and as little as possible of any kind of oil shall be used for this purpose. (This prohibition shall apply to every cylinder and valve chest for whatever purpose used.) Under ordinary conditions of working with saturated steam

the water of liquefaction derived from the steam furnishes ample lubricant for the internal working parts, but, if this does not prove sufficient, pure mineral oil only shall be employed.

Lubrication of piston rods and valve stems—

(2) Care shall be taken that the oil used for lubricating the piston rods and valve stems is not drawn into cylinders or valve chests. When main engines are fitted with forced lubrication systems care shall be taken to prevent the oil from being splashed on piston rods or valve stems, particularly from crossheads or guides.

Grease extractors—

(3) When filters or grease extractors are fitted they shall be used, except when under repairs or being cleaned. The material used in filters and grease extractors for extracting the oil from the feed water shall be cleaned or renewed as often as necessary to keep it effective and to prevent it becoming saturated or clogged with grease and inefficient. Every available means shall be employed to prevent the passage of oil to the boilers.

91. Water on bearings—

Water shall not be used unnecessarily on the bearings, but when it is used care shall be taken that it is discontinued a sufficient length of time before the engines are stopped to allow the lubricating oil to find its way to all parts of the bearing surfaces. Bearings shall not be allowed to get too warm before resorting to the use of water, if such use should become necessary, but it shall be applied at first with the greatest caution in order to avoid cracking or warping any parts as a result of too sudden cooling. Bearings shall be examined at the earliest opportunity after water has been used on them.

92. Alteration in use of boilers—

(1) As the number of boilers required for ordinary cruising and for port service is usually less than the whole

number fitted, the employment of the several boilers shall be regulated so that eventually the work will be distributed equally among the whole number, unless some peculiarity of fitting or other similar reason prevents such equal distribution being accomplished.

Forced draft with fire-tube boilers—

(2) When it is necessary to increase the speed of a vessel having cylindrical fire-tube boilers it shall be done, except in case of emergency, by increasing the number of boilers in use, under natural draft, until the entire number on board are in use, if requisite. Forced draft shall not be used on boilers of this type except in emergencies and during the power trials specified in sections 1 to 7.

Training firemen—

(3) In order that the best results may be obtained when the development of the highest power is a matter of great importance, frequent opportunity shall be given for training the firemen to work the boilers at their full capacity, under both natural and forced draft conditions. With this object in view, and to insure that the boilers in use are being worked at approximately their full capacity, when more careful firing will be necessary than is required under easier or more economical conditions of steaming, no more boilers shall be employed upon such occasion than are required for the speed ordered.

93. Handling of fires—

(1) Particular attention shall be given to the training of the firemen, especially as regards the management of the fires; and all engineer officers and fireroom petty officers shall take advantage of every opportunity to instruct the firemen how to burn the fuel in the most economical manner. Every effort shall be made to keep the steam pressure and the water level in the boilers constant, to work the fires in the most efficient and systematic manner, and to use to the best advantage all appliances for timing the

operations of firing, regulating the supply of air, and for economizing in any way in the expenditure of fuel. The engineer officer shall ascertain the most economical rate of consumption of fuel, together with the number of boilers it may be necessary to employ for any required speed and condition of steaming.

(2) When burning coal, careful attention shall be given to the management of the fires, to secure the utmost economy and efficiency of combustion. The fires shall be maintained at a uniform thickness in all parts of the furnace. Green coal shall be added to the fire at regular and frequent intervals, and shall be scattered over the entire surface. The furnace doors shall be kept open only the shortest possible time. Holes in the fire or the accumulation of clinkers in any part of the furnace shall be prevented. All lump coal must be broken up before being fired. The fires shall be cleaned at regular and frequent intervals, as often as may be necessary to keep them in good condition. Care shall be taken to remove all clinkers adhering to the grate bars. The necessary cleaning of fires shall be done as quickly as possible, in order to reduce to a minimum the amount of cold air admitted through the uncovered grate and the furnace door. The uptake dampers shall be closed while cleaning fires. The uptake dampers, rather than the ash-pit doors, shall be closed when necessary to temporarily check the rate of combustion, the closing of the ash-pit doors being liable to cause the burning or buckling of the bearer bars and grate bars. The use of water in the ash pans is unnecessary under ordinary conditions, and shall not be resorted to except when necessary to prevent clogging of the grates by excessive clinkers.

94. Temperature of boilers—

Sudden and very rapid changes of temperature in the boilers shall be avoided. The tubes shall not be unnece-

sarily exposed to cool air by opening the connection or casing doors; these doors shall not be used as dampers to check the production of steam. When circumstances permit, at least six hours shall be occupied in raising steam from cold water in other than water-tube boilers. In water-tube boilers, except when the brickwork is quite new, steam may be raised much more rapidly; but sufficient time should be allowed for thoroughly warming up the engines before attempting to move them under steam, and steam may ordinarily be raised in these boilers within the time necessary for this purpose.

95. Starting fires—

(1) Before starting fires in any boiler, all drain cocks, bottom and surface blow valves, handhole and manhole plates, and other valves and fittings not intended to remain open, shall be examined to see that they are tightly closed. The safety valves, boiler stop valves, feed check and stop valves, and water column valves shall be examined, and the water gauge and test cocks shall be tested, to see that they are all in proper working order. It shall be definitely ascertained that the valves and pipes leading to the pressure gauges are wide open. The water shall be brought to a height that is slightly below the normal steaming level. The air cock shall remain open while the water is being run down and while steam is being raised, and shall be closed after steam has formed.

(2) While steam is being raised in a boiler, close attention shall be given to all the boiler fittings and feed arrangements, to insure that they are in all respects in proper working order. Special care shall be taken, in setting up the nuts of handhole and manhole fittings, that no greater leverage is applied than that afforded by the proper spanner provided for that purpose. Ash-pit doors of automatic or balanced type shall always be left mounted while boilers are under steam. The boilers shall be connected to the

steam line only when there is a difference of pressure not exceeding ten pounds, and the boiler stop valve shall at first be only slightly opened, to allow the pressures in the steam line and in the boiler to equalize gradually. After the pressures have equalized, the stop valve shall be further opened gradually to such extent as required.

(3) Whenever steam is raised in a boiler, in order to insure that the safety valves are in good working order and to ascertain the exact pressure at which they will lift, the steam pressure shall be allowed to rise until these valves should lift if properly adjusted. This may be done after the boiler has been connected, if more convenient, but the boiler shall not be continued in use unless the safety valves have been correctly adjusted.

96. Use of blowers—

(1) The fireroom blowers may be run at any time at moderate speed for purposes of ventilation or to assist the draft.

“Natural draft” and “forced draft”—

(2) When burning coal alone, the term “natural draft” implies that, if necessary or desirable, the blowers may be run with the firerooms either open or closed to assist the draft and to supply sufficient air to the fires to support the combustion of not more than twenty pounds of coal per square foot of grate surface per hour. The term “forced draft” implies that the blowers are used to produce the greater draft pressure necessary to force through the fires the quantity of air required to support the combustion of more than twenty pounds of coal per square foot of grate surface per hour.

97. Banked fires—

Banked fires shall not be kept in water-tube boilers; nor shall heavy banked fires be kept in any other type of boilers except in emergencies, and in such cases ash-pit doors shall not be closed. When the main engines are not

to be used for twelve hours or more, fires shall be allowed to die out in all water-tube boilers, except those needed for auxiliary purposes, and when the main engines are to be used again within twelve hours light fires shall be kept spread in such boilers.

98. Hauling fires—

Fires shall not be hauled, except to prevent damage to a boiler in case of emergency. When steam is no longer required, the fires shall be allowed to die out in the furnaces, with the dampers, furnaces, and ash pits closed.

99. Automatic ash-pit doors—

When boilers are under steam the automatic ash-pit doors must not be opened so wide as to prevent proper automatic closing in case of any injury causing undue pressure within the furnaces, except during such times as may be necessary for cleaning fires or hauling ashes, upon the completion of which they shall be replaced in their automatic working position. Fire tools shall not be left in the ash pans of steaming boilers.

100. Feeding boilers—

(1) In feeding the boilers, the feed valves of the several boilers in use shall be so adjusted as to distribute the requisite supply about equally to each boiler. Strict attention shall be given at all times to maintaining the height of water in the boilers at as nearly as possible a constant level. As long as a boiler is furnishing steam the feed supply shall never be entirely shut off, even for a short period. Should any difficulty be experienced in feeding a boiler, the combustion shall be checked at once, by closing the dampers and ash-pan doors, if necessary, and steps taken to find the cause.

(2) The temperature of the feed water entering the boilers shall be maintained as high as possible. Where feed-water heaters are not fitted, the temperature shall be

as high as is consistent with the maintenance of a fair vacuum.

101. Low water—

(1) Low water in a steaming boiler is one of the most serious and most frequent emergencies that arise in a fire-room, and is liable to cause distortion of the tubes or other injury to heating surfaces, serious steam and water leaks, or the explosion of the boiler. It is generally the result either of inattention on the part of the water tender, or of his attention being diverted to other duties. Failure of the feed pumps, leaks developing in the feed discharge line, hot or low water in the feed tank, a defective check valve, or water gauges giving false indications due to defects of the cocks fitted to them are other causes which may lead to low water, if not discovered and corrected with sufficient promptness.

(2) Whenever the water in any water-tube boiler falls below the lowest try cock and out of sight in the gauge glasses the fires shall be hauled, or, if burning fuel oil, the supply of oil to the burners shall be shut off, the safety valves shall be opened cautiously to relieve the pressure gradually, and the feed check and boiler steam stop valves shall be closed. The dampers and the furnace and ash-pit doors shall also be closed. All air leaks to the furnace around these doors shall be stopped. Under these conditions the boiler will gradually cool, and any parts that may have become overheated will be subjected to an annealing process. No attempt shall be made to restore the normal water level by increasing the supply of feed water. Fire extinguishers, if fitted, or otherwise a fire hose or wet ashes, shall be used to quench or deaden coal fires before hauling them.

102. Serious steam leaks—

Whenever a large steam leak occurs in a boiler, from the sudden leaking of a tube or other cause, the following action

shall be taken, as far as the particular circumstances admit, to prevent serious injury to personnel and to reduce to a minimum the extent of damage to the boiler. The safety valves of the injured boiler shall be opened to relieve the pressure as quickly as possible. The fire extinguisher shall be opened cautiously, if fitted; or if burning fuel oil, the supply of oil to the burners shall be shut off. The furnace and ash-pit doors shall be kept closed until after the steam pressure has been reduced to less than fifty pounds, when, if the fires have not been put out by the leak or by the fire extinguisher, they shall be deadened by a fire hose or wet ashes and then hauled. After the fires are out the doors shall be closed and all air leaks to the furnace stopped and the boiler allowed to cool slowly. The stop valve on the injured boiler shall be closed. If the blowers are running they shall be kept going and their speed increased, if necessary, to drive the escaping steam up the smoke pipe and keep it out of the fireroom; hence the dampers shall be kept open. Except in the case of low water when consequent overheating is involved, the feed supply shall be continued until the fires are out, to prevent the heating surfaces becoming uncovered and burned; in such case, the auxiliary feed pump shall be started and after the auxiliary feed check has been opened, the main feed supply shall be shut off, if other boilers are being fed from the latter. Special care shall be taken to maintain the water at the proper height in all other boilers in use and to provide additional water from the reserve tanks, if necessary, to prevent a shortage in the main feed tanks.

103. Accidents in general—

In all cases of accident to boilers or machinery, every endeavor shall be made to localize the injury. The compartment involved shall be isolated to prevent escaping steam getting into other compartments and interfering with proper attendance on other boilers or machinery in use.

All men on duty shall remain at their proper stations, give strict attention to the machinery in operation, and avoid that inattention sometimes due to excitement which may lead to further damage. When considerable leaks of steam occurs in a fireroom the upper part of the compartment generally becomes filled with steam, and men shall not be allowed to go up the fireroom ladders at such times on account of the great danger of their being seriously injured or overcome by inhaling the steam. The best avenue of escape, if it becomes necessary to abandon the compartment, is to a coal bunker or to another compartment on a low level.

104. Economy of auxiliaries—

With a view to effecting the utmost economy in fuel consumption for auxiliary purposes the following requirements shall be observed:

(a) Steam shall be kept fully shut off from all engines, steam and exhaust pipes, etc., when not required for use. If any additional steam power beyond the usual requirements be needed for temporary use due notice shall be given in advance, and also as soon as the necessity ceases, in order to avoid keeping the steam at an unnecessarily high pressure, an engine working when not needed, or an uneconomical number of boilers in use.

(b) The use of capstan engines, winches, ash hoists, deck pumps, sanitary pumps, and galley, pantry, or radiator heating systems, etc., shall be limited to the minimum necessity of their legitimate functions.

(c) Electric lights, fans, or other electric apparatus requiring the expenditure of power shall not be left turned on when not required for immediate use.

(d) The issue of fresh water shall be under strict supervision to prevent waste.

105. Oil-burning installations—

(1) Upon starting fires in a boiler, care shall be taken before lighting fuel-oil burners to insure that the furnace

and ash pit are clear of oil and well ventilated, and, in order to avoid a possible back flash, the fireman shall stand well clear of the sightholes and other openings in the furnace front. In lighting burners in addition to those required for raising steam, the oil shall not be turned on until the blowers have been started and the furnace cleared of gas. Similarly, in shutting down, the blowers shall be kept running until all the burners have been shut off. Should a burner become extinguished accidentally, the cause may be due to (a) water mixed with the oil coming from the oil tanks, or from leaky heaters; (b) solid matter choking the burner, due either to fault of the strainers or to carbonizing of the oil in the burner, or (c) water passing over with the oil from the tanks or air chambers on the pumps or oil line. When a burner is choked it shall be removed at once and thoroughly cleaned. The cleaning shall be very carefully done, care being taken that the outlet holes are not roughened, enlarged, or altered in shape. Burners shall never be left in place disconnected.

(2) When heaters are fitted, special effort shall be made to detect promptly any leaks from the oil to the steam side of the heater. Such leaks allow the oil to pass directly to the boiler water, and, in order to prevent this, the steam pressure on the heater shall be kept higher than the oil pressure, when practicable. At least once during each watch the drain from the oil heaters shall be tested for the presence of oil, and if oil be found the heater shall be drained and disconnected at once.

(3) When boilers are fitted to burn oil in combination with coal, it shall be borne in mind that the installation is designed to obtain the full power from the boilers when burning coal alone. The oil is provided to make it possible to maintain production of steam on prolonged full-power runs after the coal fires become dirty, or when the trimming of the coal to the firerooms becomes difficult. Therefore, in order to prevent undue forcing when burning both

coal and oil, the rate of burning the oil shall not be allowed to exceed eleven pounds per square foot of grate surface per hour. In burning oil with coal, special attention shall be paid to the opening of the ash-pit doors for regulating the quantity of coal burned. When the fires are clean these doors shall be nearly closed and their opening gradually increased as the fires become dirty. The fires shall be worked so that the grate is well covered, with no holes, and they shall be of moderate thickness and even surface. Care shall be taken in handling the fire at the front of the furnace to avoid blocking the air cones and overheating the furnace fronts or cones. The coal shall be fed in small quantities at a time, and the fire doors shall be kept open as short a time as possible. The fire shall be cleaned as would be done when burning coal alone, and, while being cleaned, the burners in that vicinity shall be shut off. The air pressure and the supply of coal and oil shall be carefully regulated, so as to produce the most efficient combustion of both fuels, with a minimum of smoke. Should excess smoke occur, the cause may be (a) fires too heavy, (b) insufficient air pressure in the fireroom or improper opening of air register, or (c) ash-pit doors open too wide, or holes in the fires, thus preventing a sufficient proportion of air passing through the air cones.

106. Salt feed—

(1) Any indications of the presence of sea water in the feed tanks, or of considerable increase in salinity of the water in the boilers, shall be investigated promptly and the defect corrected with the least possible delay. As a rule, when sea water becomes unavoidably admitted to the boilers, blowing down shall not be resorted to until the salinity exceeds six hundred grains of chlorine per gallon in fire tube, Babcock & Wilcox and similar types of boilers, and one hundred and fifty grains in small bent tube or torpedo boat boilers. When bottom blow valves

are used to reduce the salinity of boilers under steam, they shall be quickly opened wide for a few seconds only, and at intervals of not less than four hours. Too frequent use of these valves shall be avoided, as it causes them to leak, indirectly wastes fuel, and promotes corrosion.

Emptying boilers—

(2) When it is required to empty the boilers, they shall not be blown down, as this practice is liable to cause leaky tubes and joints, but the water shall be allowed to remain until it becomes cool, and shall then be either pumped or drained out.

107. Evaporators—

As the efficient operation of the evaporators depends upon varying conditions of steam pressure, height and density of water, etc., according to the state of the heating surfaces at any time, constant attention shall be given to secure the best working conditions at all times, in order to obtain the maximum production of water at the most economical rate of expenditure of fuel. Evaporators shall be operated in double effect when so fitted. The density of the water shall not ordinarily be allowed to exceed $3/32$ by the salinometer, otherwise there is danger of hydrochloric acid being produced by decomposition of magnesium chloride, which, passing to the distillers, will render the fresh water acid. The fresh water distilled shall be tested at frequent and regular intervals, in order to insure that it is being produced in a pure state and free from salt.

108. Oil in internal-combustion engines—

In internal-combustion engines designed for splash lubrication in the crank cases, care shall be taken not to carry the level of the lubricating oil too high. If the level is kept much higher than is necessary for proper lubrication, the oil is liable to pass the pistons and burn in the combustion spaces, not only fouling the cylinders and clogging the

valves and piston rings, but resulting in unnecessary waste of the lubricating oil.

109. Pneumatic system—

(1) In starting an air compressor, it shall be run slowly until it becomes warm and until there is a pressure of at least twenty-five pounds in the accumulator to provide an air cushion. To avoid overheating of the air cylinder, compressors of the Westinghouse or similar type, not fitted with water jackets, shall not be run at too high a rate of speed, and care shall be taken that the governor acts properly.

(2) After using air compressing machinery for any purpose, great care shall be taken to see that the engines, pumps, separators, charging columns, and reservoirs are blown out and thoroughly drained of water. The pressure gauges shall be left open to the spaces to which they are attached, so that any pressure that might remain in the system will be indicated, in order to avoid accidents upon disconnecting any parts.

(3) A spare set of leather cup washers shall always be kept ready for use, such leathers being kept in tins filled with neat's-foot, castor, or other oil suitable for keeping them soft and in proper condition.

(4) The oil used for lubricating the internal parts of the air cylinders when the packings are of leather shall be neat's-foot, or, if that is not obtainable, castor oil or other suitable oil shall be used. Such oil, however, shall not be allowed to enter any steam cylinder.

110. Preparation for collision—

(1) Before going into action, all articles which might be displaced by a collision shall be secured or so disposed that no injury thereby can be done to the machinery or to any person.

(2) When intending to ram, or likely to be rammed, notice shall be given from deck to the engine room by any

prompt method of communication, so that men, tools, etc., may not be thrown down or against moving parts of the machinery.

(3) To prevent the passage of water from the boilers into the engines when collision takes place, the separators shall be blown out and their drains left open until the engines are safely reversed.

(4) In ramming, being rammed, and generally in cases of collision, men shall go to their stations for starting all bilge pumps and other means provided for freeing the ship of water in case of dangerous leakage.

111. Stowage of coal—

(1) During the intervals between steaming periods, and at other times when it may be done to advantage, the coal shall be trimmed from the upper and more remote bunkers into close proximity to the bunker doors of the firerooms where it will eventually be required for use. This is specially important preparatory to steaming at a high rate of speed, when a considerable supply of coal will be needed. The engineer officer shall keep himself informed of the general distribution of coal in the bunkers.

(2) Coal shall not be stowed in the firerooms in such quantities as to interfere with working the boilers or to cover up the handles or wheels of valves or to get into the bilges, thereby possibly choking the pump suctions and strainers and endangering the safety of the ship.

Section 10.—CARE AND HANDLING OF COAL.

112. Wet coal not to be taken on board—

(1) Coal shall not be taken on board wet if it is practicable to avoid it, and care shall be taken to keep it dry in the bunkers, as moisture sometimes causes a rapid and dangerous generation of heat and gas, resulting in spontaneous combustion. Before the docks are washed down

after coaling the solid bunker plates must be replaced and made tight to prevent water getting into the bunkers.

Height of stowage in bunkers—

(2) The stowage of coal in the bunkers shall be limited to the height of the lower edge of the beams, in order that sufficient vacant space above the surface of the coal shall be preserved for proper ventilation. The contents of the bunkers shall be calculated on this basis.

Ventilation of bunkers—

(3) The ventilation pipes fitted to the bunkers shall be kept clear, and they shall always be kept open for ventilation except when running the blowers and a loss of air pressure in the firerooms through open bunkers would be caused thereby. The plates of all fixed coaling trunks and coal bunkers not provided with permanent ventilation fittings shall be taken off periodically to ventilate these spaces. This should be done at frequent intervals after coaling, as the evolution of gas owing to the breaking up of the coal is very rapid during and for some days after the operation of coaling ship. It must be borne in mind that to secure efficient ventilation there must be at least two openings—one for the admission of pure air and another for the escape of foul air—and where permanent ventilation fittings do not include both, the bunker plates should be taken off periodically as required above. Care shall be taken to thoroughly ventilate such bunkers before any men are sent to work in them.

Precautions regarding open lights in bunkers—

(4) No open light shall be permitted in a coal bunker or within twenty feet of an opening into it until the bunker has either been thoroughly ventilated with all the bunker plates removed or has been explored with a safety lamp and found free of explosive gas. In any case where the limitation of twenty feet is impracticable the distance shall be as great as possible.

113. Coal gas in bunkers—

(1) The gas to be guarded against is methane, CH_4 , marsh gas, which, in an explosive mixture with air, is known as fire damp. The gas is lighter than air and therefore tends to accumulate in the upper portions of bunkers. This gas is given off from all bituminous coals, in quantities varying with the nature of the coal. With the coal ordinarily used in our service—Pocahontas, New River, Georges Creek, etc.,—there is little probability of dangerous accumulations of the gas. With other coals, notably certain Welsh coals, this probability is greater.

In small quantities this gas is not dangerous. A mixture of the gas and air containing 5.5 per cent of the gas is, however, inflammable, and 7 per cent is explosive.

Indication of gas by safety lamp—

(2) In the Beard-Deputy-Marsant type of safety lamp presence of gas in the bunker will be indicated by a blue cap on the yellow flame of the lamp. The height of the blue cap increases with the percentage of the gas present. To facilitate the determination of the percentage of the gas the platinum wire indicator is provided. With the flame so adjusted that in fresh air the lower wire will just glow in the dark, the glowing of the upper wires when the lamp is taken into a bunker will measure the percentage of gas present, in increments of one-half per cent up to 3 per cent, which is the reading of the topmost wire.

In reading the platinum wire indicator the brass bonnet surrounding the gauze of the lamp should be removed. (This bonnet renders the lamp safe under all conditions in explosive mixtures of the gas. Without it there is a chance of igniting the gas from the flame of the lamp through the gauze in case the lamp is accidentally dropped in fire damp.) The presence of the bonnet reduces the height of the blue cap in the flame. Though an indication of the presence

of gas can be obtained with the bonnet on, an accurate determination of the percentage of the gas can only be obtained with the bonnet removed.

The presence of any gas may of course indicate the possibility of more extensive accumulations in pockets, and until greater experience has been had with the use of the lamp it is considered that no naked light should be allowed in a bunker if the safety lamp shows any indication of the presence of gas.

Use of safety lamp—

(3) The precautions regarding open lights in bunkers shall apply—

(a) When a bunker containing Navy standard coal, or connected with one containing such coal, is opened after having been closed longer than sixty hours.

(b) When a bunker containing other than Navy standard coal, and particularly Welsh coal, or connected with one containing such coal, is opened after having been closed longer than twelve hours.

(4) If any indication of fire damp is found it shall be removed by ventilation, assisted, if necessary, by a blower, before naked lights are allowed in the bunker, bearing in mind the fact that the gas is lighter than air.

(5) The tests for fire damp shall be made by a reliable man of the rate of water tender or chief water tender.

(6) The safety lamps shall be cleaned after use, and care taken that the gauze is not torn, as a hole in it renders the lamp unsafe. They shall be stowed in places accessible to the bunkers, preferably in charge of the persons charged with their use.

(7) Only pure lard oil or sperm oil should be used in the lamp. Kerosene is not suitable, owing to its tendency to deposit soot on the gauze. This deposit may glow sufficiently to ignite fire damp.

114. Spontaneous ignition of coal; initial causes—

(1) The cases of spontaneous ignition of coal sometimes involve seemingly contradictory facts, owing to the primary and contributory causes being present in different degrees. The principal chemical cause of spontaneous ignition of bituminous coal is the condensation and absorption of oxygen in the air by the fixed carbon in the coal, which is accompanied by the evolution of heat, and this chemical activity is in turn accelerated by heat. When coal is heated a little above 212° the power of absorbing oxygen is increased, and in a few hours will absorb sufficient to give a perceptible increase in weight; consequently, the amount of increase in weight is an indication of the liability to spontaneous ignition. Dry coal absorbs oxygen more quickly than wet coal, but the presence of moisture increases the action of the already-absorbed oxygen upon the hydrocarbons of the coal and so causes increase in heating.

Secondary causes—

(2) A secondary cause is the action of moisture on iron pyrites (FeS_2). The heating effect of this cause is very slight, but its indirect effect is to cause swelling and breaking of the coal, thus exposing fresh surfaces for the condensation and absorption of oxygen.

Some coals containing a large amount of pyrites are notably free from liability to spontaneous ignition, and on the contrary some containing a small amount of pyrites furnish cases of spontaneous ignition. The disulphide of iron is found in coal in different forms, sometimes as a dark powder resembling coal, and other times in golden layers in the cleavage of the coal (coal brasses); it gives the reddish-brown color to the ash in some coals.

Volatile matter—

(3) An accessory to these chemical causes is the combustible volatile matter in the coal. The heat evolved by

the first cause stimulates the chemical action of the condensed oxygen with the volatile hydrocarbons and fixed carbons; this chemical action further evolves heat; coal being a poor conductor of heat, the temperature rises to the ignition point and the combustion is supported by the combustible volatile.

Contributory causes; size of coal—

(4) The coal being broken into small pieces naturally presents a greater surface for the absorption of oxygen, which increases the effect of the first cause of liability to spontaneous ignition. Fires in cargoes generally start under hatchways, where the percentage of slack and fine coal is greatest.

Height of coal in pile—

(5) By increasing the height of the pile of coal as stored the amount of nonconducting material is increased, and heat evolved in the interior of the pile has less chance of escape. In addition, there will be more breakage of the coal in larger piles.

Moisture in coal—

(6) Absorption of oxygen in wet coal is at first retarded, but the presence of moisture increases the action of the oxygen upon the volatile matter in coal and this increases the heating. The combination of many substances with oxygen is prevented if both are perfectly dry. On the other hand, it has been proposed to wet the fine coal under hatchways of large ships loaded in warm weather.

Effects of climate—

(7) It is evident that coal shipped to a cold climate would be less liable to spontaneous ignition than would coal passing through the Tropics, since in the latter case there is increased temperature and slower removal of heat.

Local heating—

(8) The most usual causes of local external heating are those due to heat from a boiler or steam pipe commun-

cated to a coal bunker. If the bulkhead of a bunker containing coal with a tendency to absorb oxygen is kept at 120° F. there is a great chance of spontaneous ignition in a few days. The seat of the fire may not be close to the bulkhead, because there may be a smothering effect of the coal next to the bulkhead, with sufficient radiation, resulting in simply charring the coal, the ignition taking place nearer the center of the pile. Waste, oily with fatty oils easily oxidized, may start a fire spontaneously, but mineral oil is said to retard heating.

Defective ventilation—

(9) Defective ventilation is that which renews air sufficiently to support combustion faster than it removes the heat to reduce the temperature below the point of ignition.

115. Preventive measures—

(1) Coal should contain as large a percentage of lump and as little slack as possible, as in the latter resides the primary causes of spontaneous ignition. It should not have a high percentage of combustible volatile matter.

Newly mined coal undesirable—

(2) Coal should be at least a month from the mines, because it evolves marsh gas and absorbs oxygen more readily when it is newly mined.

Permissible amount of moisture—

(3) It should not be loaded or stored in a wet or damp condition. The maximum percentage of moisture should be 3 per cent, and that only when the coal is to be unloaded and used in the near future.

Precautions to be observed in colliers—

(4) Ventilation is ordinarily effective on naval vessels on account of the comparatively small amount of coal in the bunkers and the access at top and bottom. In colliers, however, perfect ventilation is impossible on account of the amount of coal in the cargo spaces, and the cargo hatches should be battened down to exclude the fresh supply of air. Hatch covers, however, should be removed

at times when the external air is cooler than the surface of the coal which shows signs of heating.

Obtaining temperature of coal—

(5) Thermostats are installed on naval vessels to give warning of increase of temperature in bunkers, and in colliers handhole plates should be fitted to the cargo spaces to permit dropping thermometers in the upper part of the cargo holds to obtain the temperature therein. The temperature of all cargo holds should be taken daily.

Characteristic odor—

(6) When coal is heating it gives out a characteristic and penetrating odor. The gases evolved consist of nitrogen, water vapor, carbon dioxide, carbon monoxide, hydrocarbons of a paraffin series, and sulphuretted hydrogen.

116. Extinguishing fire in bunkers with steam—

(1) An effective means for extinguishing the fire in bunkers is the introduction of steam to the bottom of the pile. Some vessels in the Navy are fitted with smothering pipes introducing the steam into the top of the bunker, which is nearly as effective. The atmosphere of steam will not support combustion.

Extinguishing fire with water—

(2) If water be used to extinguish the fire, it should be admitted to the bottom of the bunker, for the reason that the bottom is probably nearer the seat of the fire. It has been found that in applying water on top of a pile the flow is so impeded by the coal itself and by the caking of the coal above the fire as to have very little effect if the bunker or hold is filled with coal.

Removal of coal—

(3) If none of these means are provided, the removal of the coal from the bunker or hold until the seat of combustion is reached should be resorted to. Coal that has been subject to spontaneous ignition and extinguished can be replaced in a bunker with perfect safety.

Section 11.—SPECIFICATIONS FOR FUEL OIL.

117. The specifications and detailed information regarding facilities, conditions, and methods of delivery of fuel oil will be found in the "Contract bulletin for fuel oil for use ashore and afloat," published by the Bureau of Supplies and Accounts.

Section 12.—RECEIPT OF FUEL OIL FOR NAVAL VESSELS.**118. From Navy fuel ship or naval vessel—**

The commanding officer of the vessel delivering the oil shall furnish the commanding officer of the vessel loading with a copy of the analysis of the oil.

119. From Navy storage tank or barge—

When fuel oil is received from a Navy storage tank or from naval barges, the officer filling the requisition shall furnish the commanding officer of the vessel loading with a copy of the analysis of the oil.

120. From contractor—

When fuel oil is received directly from the contractor by means of pipe line, barge, or tank cars, the contractor shall furnish the officer making the purchase with two copies of the analysis of the oil, one of which shall be delivered to the commanding officer of the vessel loading. The commanding officer of the vessel loading shall have three samples of the oil taken, two of which shall be transmitted, without delay, to the chemist at the nearest one of the following navy yards: New York, Mare Island, Pearl Harbor, and Olongapo, and the third retained on board for transmission to the contractor's chemist, in case any question should arise as to the quality of the oil. The samples sent to the chemist shall be numbered serially, beginning a new series each fiscal year. The samples shall be accompanied by a letter of transmittal giving the serial

number of the sample, name of the contractor, number of the contract, amount of oil received, and the date, place, and manner of delivery, with the name of the barge or name and number of the tank cars, if used; and a copy of this letter shall be sent to the Bureau of Steam Engineering.

121. By fuel ships—

When fuel oil is received in cargo lots by fuel ships at refineries or tank farms, the quantity and quality of the oil received shall be determined as specified in the contract, and the commanding officer of the fuel ship shall transmit to the Bureau of Supplies and Accounts a report of the loading showing the amount of oil received and the analysis of the oil as determined by the authorized inspector. A copy of this report shall be forwarded to the Bureau of Steam Engineering.

122. From commercial supplier—

Fuel oil shall not be received from any commercial supplier who is not a party to the annual contract for supplying fuel oil for use afloat, except in ports where no contracts are in effect or in cases where the regular contractor is unable to make satisfactory delivery. Should such action become necessary, the procedure followed shall be the same as given in Art. 120, except that the oil shall not be taken on board until a complete analysis has been made by a chemist. In this case the letter of transmittal shall also include the chemist's analysis, a statement of the reasons for such loading, and a description of the firm's facilities at the place of delivery. A copy of this letter shall be attached to the quarterly fuel oil report rendered to the Bureau of Supplies and Accounts.

123. Responsibility for quantity—

The commanding officer of the vessel loading shall be responsible for the quantity received, which shall be determined as specified in the contract.

124. Sampling—

Samples to be sent to the chemist shall be taken, if practicable, through a pet cock on the line or through a leaky coupling. Whenever practicable, the contractor's representative shall be given an opportunity to witness the sampling of oil.

125. Loading fuel oil—

The loading of fuel oil shall be governed by "Instructions for care and handling of fuel oil" (sec. 13), "Contract bulletin for fuel oil afloat," "Instructions for testing Navy fuel oil," and by such instructions as may be issued modifying or supplementing the foregoing.

Section 13.—CARE AND HANDLING OF FUEL OIL ON OIL-BURNING VESSELS.**126. Fuel-oil characteristics—**

Fuel oil is inert, nonexplosive, very difficult to ignite in bulk, and not capable of spontaneous combustion. The vapor from this oil, however, is explosive when mixed with air. This vapor is heavier than air and tends to accumulate in low levels, such as bilges and bottoms of tanks, where it may remain undiscovered until ignited by a naked light or spark. It is always present in a partly filled oil tank, or one that has contained fuel oil and from which the vapor has not been removed by artificial means, and it is expelled through the vents from the fuel-oil tanks while they are being filled. A leak allowed to endure in any part of the oil-burning system may result in an accumulation of this explosive vapor unless such leak is located in the path of air to the furnace. Ignition of the vapor may be caused by an open light, electric spark, or spark made by striking metal, heat of the filament of a broken electric lamp, smoking, sparks from funnel or galley, or fires under

boilers. An oil fire can be extinguished by dry sand, steam, or chemical extinguishers, but not by water.

127. Safety precautions—

(1) To prevent the accidental explosion of oil vapor and to insure the safe handling and stowage of fuel oil, the precautions prescribed in the Instructions for the Care and Operation of Fuel Oil Burning Installations shall be strictly observed.



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